ESTIMATION OF GENETIC PARAMETERS FOR ELK HUNTING TRAITS IN JÄMTHUNDS

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Tiivistelmä — Referat — Abstract

Tämän tutkielman tavoitteena oli arvioida jämtlanninpystykorvien hirvenmetsästysominaisuuksien perinnöllistä vaihtelua. Tarkasteltavia ominaisuuksia oli yhdeksäntoista. Ominaisuuksille arvioitiin periytymisasteet ja toistumiskertoimet sekä geneettisiä ja fenotyyppisiä korrelaatioita. Lisäksi osapopulaatiolle laskettiin sukusiitosaste ja perinnöllinen edistyminen ominaisuuksissa.

Aineistona käytettiin Suomen harmaahirvikoirajärjestöltä saatua koeaineistoa virallisista hirvenhaukkukokeista vuosilta 2012-2016. Tuloksia oli yhteensä 46221, joista jämtlanninpystykorvilta 23335 tulosta. Sukupuu saatiin Suomen Kennelliitolta ja se kattoi 31544 jämtlanninpystykorvaa. Kiinteiden tekijöiden merkitsevyys testattiin R-ohjelmalla käyttäen yksisuuntaisen varianssianalyysin F-testiä. Sukupuu karsittiin ja sukusiitosaste estimoitiin RelaX2 1.54-ohjelmistolla. Varianssikomponentit estimoitiin DMU-ohjelmistolla käyttäen AI-REML-menetelmää.

Periytymisasteiden arviot olivat matalia ja vaihtelivat 0,00-0,047. Korkein periytymisaste saatiin haulle ja matalin työskentelyn aikaiselle tottelevaisuudelle. Geneettiset korrelaatiot vaihtelivat -0,25-0,98 ja korkeimmat niistä saatiin useimmille haukkuun liittyville ominaisuuksille. Perinnöllinen edistyminen on ollut positiivista kaikissa muissa ominaisuuksissa, paitsi tottelevaisuusominaisuuksissa. Sukusiitosaste oli vuonna 2016 syntyneillä koirilla keskimäärin 7,03 % ja sukusiitosaste on laskenut 0,26 % syntymävuosina 2006-2016.

Ominaisuuksiin vaikuttavia selittäviä muuttujia on runsaasti ja koeaineisto perustuu subjektiivisesti arvioituihin tekijöihin. Jalostusarvojen ennustamista mahdollista kehittää keräämällä tietoja koeolosuhteista kokeen aikana ja käyttämällä arvosteluasteikkoa laajemmin ja objektiivisemmin. Jalostusarvoja – tärkeimpien ominaisuuksien osalta on mahdollista käyttää seuraavan sukupolven vanhempien valinnassa.

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Tiivistelmä — Referat — Abstract
The aim of this study was to estimate the genetic parameters of elk hunting traits in Jämthunds. There were nineteen traits under consideration. Heritabilities, repeatabilities, and genetic and phenotypic correlations were estimated for the traits. Also, coefficient of inbreeding and genetic trends were estimated.

The data consisted of results from official elk hunting trials collected by Suomen Harmaahirvikoirajärjestö ry in 2012-2016. There were 46 221 results, from which 23 335 of Jämthunds. The pedigree data was provided by The Finnish Kennel Club and it included 31 544 Jämthunds. Significance of the fixed effects was estimated using F-test in analysis of variance with RStudio 1.0.136. The pedigree was pruned with RelaX2 1.54-pedigree analysis programme. Variance components were estimated with DMU-package using AI-REML-approach.

The estimated heritabilities were low and varied between 0.00 and 0.047. The highest heritability was obtained for search and the lowest for obedience during work. Genetic correlations varied from -0.25 to 0.98, and the strongest were estimated for most of the bark related traits. The genetic trend has been positive in all traits, except for obedience traits. The coefficient of inbreeding for dogs born in 2016 was approximately 7.03 %, and the coefficient of inbreeding has decreased 0.26 % in the last decade.

There are multiple non-genetic factors that affect the traits, and the data is based on subjectively evaluated variables. It is possible to improve genetic evaluation by collecting more information on trial conditions, by using the whole scale of points during the evaluation, and by making more objective evaluations of the traits.

The estimated breeding values of the important traits can be used in selection of the parent of the next generation.

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APPREVIATIONS AND SYMBOLS

μ	Mean
σ	Standard deviation
CV	Coefficient of variation
GPS	Global Positioning System
N	Number of obervations
na	Not applicable
ns	Non-significant

1 INTRODUCTION

Size of the elk population in Finland at the end of the hunting season 2016 was around 90 000 (Pusenius et al. 2018). The elk population has been most dense at the coast of Ostrobothnia and in the Uusimaa region, the density of the population being more than four elks per thousand hectares (Pusenius et al. 2018). The least dense elk population has been in Lapland, the density of the population being approximately 1.8 elks per a thousand hectares (Pusenius et al. 2018). Every year approximately 54 000 elks were hunted in Finland between 2006 and 2016 (Luke 2017). One elk makes about 130 kilograms of meat, and the value of the meat is estimated to be 5 to 7 euros per kilogram (Luke 2017).

Elk have been reported to cause significant damage and economical losses to both forestry and agriculture (Petäjistö & Matala 2015). In addition, almost 2 000 elk-vehicle collisions occur each year in Finland, and on average 155 lead to personal injuries and 6 to fatalities (Niemi et al. 2017). Not only does elk hunting reduce elk-vehicle collisions and supply meat, it also provides recreational benefits for the hunters (Pellikka 2016).

Dogs have been used for elk hunting in Finland as early as the 17th century (Hämäläinen 2001, ref. Niemi et al. 2017). Use of dogs in elk hunting has gained popularity in Finland during the last two decades (Niemi et al. 2014). Dogs have been used in elk hunting at least on 80 % of the hunting days, varying locally from 41 to 99 % (Niemi et al. 2014). New technology, such as GPS-collars, has increased the use of dogs in elk hunting (Niemi et al. 2014).

Dogs' hunting traits are evaluated in elk hunting trials. The trials take place in normal hunting conditions. Approximately half of the Finnish annual elk hunting trial results are from Jämthunds. Even though, dogs are vastly used in elk hunting little is known about the genetic parameters behind elk hunting performance. The last estimates of heritabilities and genetic correlations between hunting traits of Finnish populations are from 1990's (Karjalainen et al. 1996, Liinamo et al. 1997). Thus there is need to re-estimate the genetic parameters of the elk hunting traits in Finnish elk hunting dog populations.

The objective of this study was to estimate heritabilities and genetic correlations of the elk hunting traits in Jämthunds. Results from this study are readily to be used in breeding value estimation of Jämthunds.

2 LITERATURE REVIEW

There are several Nordic elk hunting breeds such as Norwegian Elkhound Grey, Norwegian Elk Hound Black, Jämthund, East Siberian Laika, Russian-European Laika, West Siberian Laika, Finnish Spitz, Karelian Bear Dog, and Norrbottenspitz (SPJ 2018, SHHJ 2018, SLJ 2018). Based on annual registrations, Jämthund had the most registrations among elk hunting breeds in Finland in 2018 (KoiraNet 2019).

2.1 Jämthund

Jämthund (also known as the Swedish Elkhound) is an ancient dog breed originated from Sweden (FCI 2003). Jämthund was recognized as its own breed in 1946 after being separated from Norwegian Elkhound (FCI 2003). The Jämthund breed is a member of Fédération Cynologique Internationale group 5 “Spitz and Primitive type” and belongs to section 2 “Nordic Hunting Dogs” (FCI 2003). Based on annual registrations, Jämthund was the second most popular breed in Finland in 2018 with 1 394 Jämthunds registered (KoiraNet 2019). The breed organization for Jämthunds in Finland is Suomen Harmaahirvikoirajärjestö ry (SHHJ 2008).

Jämthund is one of the largest among the elk hound breeds (Mujunen 2004). The breed standard characterizes Jämthund as a courageous and energetic, yet calm breed (FCI 2003). The size standard for males is 57–65 cm and for females 52–60 cm (FCI 2003). Color of the dog is ideally light and dark grey with characteristic markings (Figure 1) (FCI 2003). The breed standard lists aggressiveness and overly shyness as disqualifying faults (FCI 2003). Compared to Norwegian Elkhounds the Jämthund is larger, more rectangular, and has less fur (Mujunen 2004). Large size and rectangular structure makes it easy for the dog to move in forest by trotting, and makes the Jämthund a durable elk hound (Mujunen 2004).

Figure 1. Jämthund (FCI 2003)

2.2 Hunting traits

Hunting traits are natural part of a predatory motor sequence including parts of orient, eye-stalk, chase, grab-bite, kill-bite, dissect, and consume actions (Coppinger & Coppinger (2001, ref. Udell et al. 2014)). Hunting behavior of dogs generally includes searching, pointing, following, stopping, and killing the game. Different types of hunting breeds make use of different parts of the predatory motor sequence – some parts being exaggerated and some suppressed by selection. Elk hounds make use of the parts of orient, eye-stalk and chase. Grab- and kill-bites are absent. A successful hunting event for an elk hound comprises of finding and following the game efficiently yet keeping in touch with the owner (barking, returning to the group), and stopping the game by barking, keeping the game in place, and informing the owner about the find. Hunting event calls for both courage and caution, ability to work independently but willingness to keep in touch with the group, and also calls for stamina of the dog.

2.3 Elk hunting trials

The official elk hunting trials in Finland are regulated by the rules approved by the council of the Finnish Kennel Club (SKL 2012). Based on the international elk hunting trial rules (SKL 2017b) “The objective of elk hunting trials is to study and test the elk hunting ability of dogs for purposes of breeding selection, to maintain elk hunting as a high quality dog sport, to develop the skills and cooperation of people active in the sport, and to create possibilities for competition based on these rules”. The description and rules of the trial given below are based on SKL (SKL 2012).

The trial season starts each year on the 20th of August and ends on the 31st December. There are four types of trials; general, between members (of a club), international, and “other competitions” assigned by a separate rule or regulation by the Finnish Kennel Club. The trials are “one class, single-day”-type of trials. Trial fields are randomly assigned excluding those in long trials. A dog representing a breed subject to Suomen Harmaahirvikoirajärjestö ry, Suomen Laikajärjestö ry, or Suomen Pystykorvajärjestö is allowed to attend a trial. The dog is should be registered, ID marked, and at least nine months old in order to validate for the trial.

Ten traits are evaluated during the elk hunting trial: search, efficiency, bark to hold, quality of bark, following, stopping, bark time, audibility, frequency, and obedience. Search is evaluated based on how long circles the dogs makes when trying to find elk. The dog should go far enough from the group (several kilometers) with good speed, but not too far. There is no rule for the shape of the ranging round in addition to that it should be efficient– it depends on the course of the dog and how the group approaches the ranging dog (Figure 2). Usually the group moves during the dog’s ranging round.

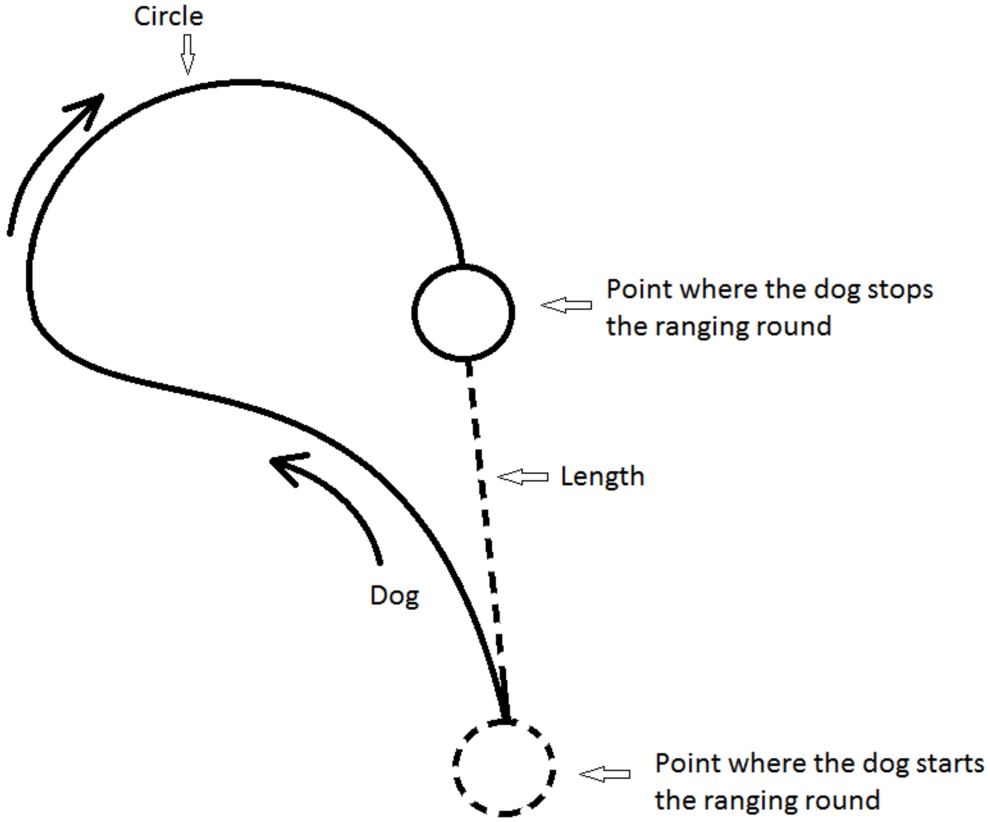


Figure 2. A schematic figure of circle and length from a ranging round. Circle is depicted as the solid line and length as the dashed line.

Evaluation of the efficiency is based on how well the dog uses its senses and the environment to find an elk, and in what weather conditions the dog works. Tracking and fast, independent, and distant find are highly valued. Ideally, the dog barks continuously for more than an hour to hold the elk in place. Bark to hold is evaluated based on the time spent barking or re-barking if the elk happens to move. Quality of bark is graded based on how well to dog's work on elk provides shooting opportunities – ideal is three shooting opportunities accompanied with the elk being driven off three times. For an ideal performance on following the dog should be willing to follow an escaping elk for at least five kilometers or for more than one hour. To test the dog's ability to stop the elk, elk is driven off multiple times. The dog should start steady barking after escape, and keep it up long enough. Bark time is the sum of the time the dog spends continuously barking, whether it is steady or moving, and on one or more animals. Audibility of the bark is evaluated based on environmental conditions. Ideally, the bark is frequent and constant without long pauses, and is graded by frequency. Obedience consists of sub points given during search, work, and after trial. It expresses the dog's willingness to follow commands and keep in contact with the owner. The dog is ought to be put on a leash and to obey recalls on first attempt.

The searching time is limited to 360 minutes and working time is limited to 300 minutes. If the dog will not start searching game within 60 minutes from being unleashed the trial will be interrupted. Working time is terminated not later than two hours after darkness has fallen (SKL 2012). A find on first ranging round gives automatically one point for obedience and cooperation during search.

If the owner or handler chooses to withdraw the points will be given but the final points will be zero. If the judge interrupts the dog's performance, the trial will be evaluated and points including total points will be given. If the dog is barred from the trial the trial will be evaluated and points given but total points will be zero. In case of disqualification the trial is not evaluated and total points will be zero.

The shortest distance registered in trial report is 0.1 km and the shortest time counted is 1 minute. The scale of points ranges from zero to ten - zero being insufficient and ten being excellent. If a performance cannot be judged then no points will be registered for that part of the trial.

The trial ends as the group leashes or tries to recall the dog. An example of the trial record sheet is given in appendix 1. Rules and regulations for international elk hunting trials are given on the Finnish Kennel Club's website http://www.kennelliitto.fi/sites/default/files/media/hirv_kv_elk_hunting_trials.pdf

The final points given in the trial are set by a chief judge with the help of two field judges who work as a group but evaluate the trial independently. If the trial is a long trial one chief judge may evaluate the trial on his own. Abnormal trial conditions are taken into account in the evaluation and are noted in field report**.**

Trait are evaluated in a scale from 0 to 10. The points of each trait are weighted and the maximum sum of achieved points is 100 points (Table 1). In case of a blank trial, where the dog does not find an elk, only search and obedience during search work are evaluated leading to a maximum of 17 points in total.

For more information about the rules and regulations of elk hunting trials in Finland see the Finnish Kennel Club's web site:
https://www.google.fi/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwj5nIrqv6vTAhVGdCwKHSfQCRcQFgggMAA&url=http%3A%2F%2Fwww.kennelliitto.fi%2Fsites%2Fdefault%2Ffiles%2Fmedia%2Fhirv_kv_elk_hunting_trials.pdf&usg=AFQjCNE_RXLZcvMVd9qv7On5Jv_7MViA_Q&sig2=wQElV9-JJHPruq0O35wPoA&bvm=bv.152479541,d.bGg

Table 1. Traits and points given in Finnish elk hunting trials

Trait	Scale	Weight
Search	0-10	1.5
Efficiency	0-10	1.0
Bark to hold	0-10	1.5
Quality of bark	0-10	1.5
Following	0-10	1.0
Stopping	0-10	1.0
Bark time	0-10	0.5
Audibility	0-10	0.5
Frequency	0-10	0.5
Obedience (consisting of sub points given for obedience during search (max. 2 points), obedience during work (max. 5 points), and obedience after trial (max. 3 points))	0-10	1.0
Total	0-100	

2.4 Heritability of hunting traits

Estimated heritabilities and repeatabilities from the previous studies are presented in Table 2. Heritabilities of hunting traits are generally low (Karjalainen et al. 1996, Liinamo et al. 1997, Liinamo 2009, Wetten & Aasmundstad 2014). This may be due to non-standardized test environment, subjective evaluation, or ongoing long term selection

(Karjalainen et al. 1996, Liinamo et al. 1997, Wetten & Aasmundstad 2014). Furthermore, some actions of the dog in the hunting process are trainable to an extent. Both Liinamo et al. (1997) and Horn et al. (2017) suggest that only the traits that truly reflect the genetic differences between the dogs should be scored in order to decrease the subjectivity of the evaluation. Horn et al. (2017) suggests non-competition based characterization of traits.

Heritabilities of hunting traits varied from 0.03 to 0.12 in Norwegian Elkhounds (Wetten & Aasmundstad 2014). The heritabilities of searching and efficiency were 0.05, bark to hold 0.08, quality of the bark 0.06, following and obedience 0.04, audibility 0.11, frequency 0.12, and cooperation 0.03 (Wetten & Aasmundstad 2014).

In a joint analysis with Norwegian Elkhounds and Jämthunds the heritability for circle was 0.07, frequency as auxiliary trait 0.22, audibility 0.06, and following 0.06 (Liinamo 2009). The heritability for the frequency as a merit score was 0.06 (Liinamo 2009).

These heritabilities are similar to those estimated for hare hunting traits in Finnish Hounds varying from 0.01 to 0.15 (Liinamo et al. 1997). Heritability estimates of bird hunting traits have varied from low to moderate in Short-Haired Pointer, Wire-Haired Pointer, Breton, and English Setter (Brenøe et al. 2002, Arvelius & Klemetsdal 2013). In Finnish Spitzes heritability estimates of hunting traits varied from 0.15 to 0.17 for frequency, 0.14 to 0.15 for search, and 0.07 to 0.08 for quality of the bark and following (Karjalainen et al. 1996). Heritabilities of stopping, bark time, and time of ranging rounds were not estimated in any of the studies mentioned above.

In a study of Norwegian Elkhounds the effect of the owner on the elk hunting traits has been reported to be relatively high in traits that are trainable such as searching, finding, bark to hold, quality of the bark, and obedience (Wetten & Aasmundstad 2014). The owner effect was relatively low in traits like cooperation, audibility, and frequency (Wetten & Aasmundstad 2014).

Repeatabilities of the hunting traits have varied from low to moderate in previous studies (Karjalainen et al. 1996, Liinamo et al. 1997, Brenøe et al. 2002, Arvelius and Klemetsdal 2013). Repeatability of frequency has varied from 0.26 to 0.37 (0.12 as a merit score), search from 0.08 to 0.30, quality of the bark from 0.12 to 0.36, and following from 0.14 to 0.18 (Karjalainen et al. 1996, Liinamo et al. 1997, Liinamo 2009). The repeatability of cooperation has varied between 0.11 and 0.22, and repeatability of circuit of ranging round has varied from 0.19 to 0.38 (Liinamo et al. 1997, Brenøe et al. 2002, Arvelius & Klemetsdal 2013). In a study with Finnish Hounds the repeatability of following was 0.18, of audibility 0.25, and of efficiency 0.06 (Liinamo et al. 1997). The repeatability of obedience was 0.13 (Liinamo et al. 1997).

Table 2. Estimated heritabilities and repeatabilities from the previous studies.

Trait	h^2	r	Breed	Study
Search	0.05	-	Norwegian Elkhound	1
	0.14–0.15	0.30	Finnish Spitz	2
	0.05	0.08	Finnish Hound	3
Efficiency	0.05	-	Norwegian Elkhound	1
	0.03	0.06	Finnish Hound	3
Bark to hold	0.08	-	Norwegian Elkhound	1
Quality of bark	0.06	-	Norwegian Elkhound	1
	0.07–0.08	0.18–0.20	Finnish Spitz	2
	0.13	0.36	Finnish Hound	3
Following	0.04	-	Norwegian Elkhound	1
	0.06	-	Norwegian Elkhounds and Jämthunds	3
	0.07–0.08	0.14–0.17	Finnish Spitz	2
	0.12	0.18	Finnish Hound	3
Audibility	0.11	-	Norwegian Elkhound	1
	0.06	-	Norwegian Elkhounds and Jämthunds	4
	0.08	0.25	Finnish Hound	3
Frequency	0.12	-	Norwegian Elkhound	1
	0.22	0.37	Norwegian Elkhounds and Jämthunds, auxiliary	4

	0.06	0.12	Norwegian Elkhounds and Jämthunds, merit score	4
	0.15–0.17	0.26–0.28	Finnish Spitz	2
	0.15	0.27	Finnish Hound	3
Obedience and cooperation	0.03–0.04	-	Norwegian Elkhound	1
	0.02	0.13–0.15	Finnish Hound	3
	0.12	-	Flatcoated Retriever	5
Obedience	0.04	-	Norwegian Elkhound	1
	0.02	0.13	Finnish Hound	3
Cooperation	0.09–0.21	0.11–0.22	Short-Haired Pointer, Wire-Haired Pointer and Breton	6
	0.071–0.084	0.18–0.223	English Setter	7
	0.02	0.15	Finnish Hound	3
Circle from ranging round – blank	0.07	0.19	Finnish Hound	3
Circle from ranging round – full and blank rounds	0.07	-	Norwegian Elkhounds and Jämthunds	4
	0.17–0.21	0.29–0.38	Short-Haired Pointer, Wire-Haired Pointer and Breton	6
	0.07–0.16	0.27–0.33	English Setter	7

1: Wetten and Aasmundstad 2014 2: Karjalainen et al. 1996 3: Liinamo et al. 1997 4: Liinamo 2009 5: Lindberg et al. 2004 6: Brenøe et al. 2002 7: Arvelius and Klemetsdal 2013

2.5 Correlations between hunting traits

Genetic correlations between hunting traits have varied from low positive correlation to strong positive correlation (Karjalainen et al. 1996, Liinamo et al. 1997, Brenøe et al. 2002) (Table 3). Phenotypic correlations has been lower than genetic correlations, and have varied between low positive to moderate positive correlation (Karjalainen et al. 1996, Brenøe et al. 2002).

Table 3. Genetic and phenotypic correlations between hunting traits in previous studies.

$Trait_1$	$Trait_2$	$Correlation_{1,2}$	Study
Search	Quality of bark	0.49 (0.37) 0.29 (0.14)	1 2
Search	Following	0.83 (0.49) 0.60 (0.43)	1 2
Search	Frequency	0.31 (0.24)	1
Frequency	Quality of Bark	0.87 (0.64)	1
	Following	0.35 (0.18)	1
Quality of Bark	Following	0.07 (0.22)	2
Circle of ranging round - blank and full	Obedience	0.98–1.00 (0.53–0.61)	3

1: Karjalainen et al. 1996 2: Liinamo et al. 1997 3: Brenøe et al. 2002

3 AIM OF THE RESEARCH

The objective of this study was to estimate genetic parameters of the elk hunting traits in Finnish Jämthunds. There were nineteen hunting traits in total.

For each trait heritability was estimated using a repeatability animal model. Also analysis with a single observation (the first observation) and logarithmic transformed observations were carried out but the results from those analysis are not reported in this master’s thesis.

4 MATERIAL AND METHODS

4.1 Trial data

The trial data were obtained from Suomen Harmaahirvikoira järjestö ry. The data consisted of 46221 observations from elk hound trials organized in Finland during 2012-2016. The observations were from 9224 individual dogs representing a variety of elk hound breeds. The observations were collected from 3815 trial events (a trial event here refers to a collection of individual observations within an individual trial event). In this study only the observations of Jämthunds were considered since 23335 (50.5 %) of the observations were from Jämthunds.

Circle, time, and length from ranging rounds, both blank and full are marked on the field report. In the trial data, a maximum of seven blank ranging rounds and a maximum of four full ranging rounds were recorded. Given that there are several records of the length of the ranging round (circle), the speed of the ranging round (time), and the longest distance from the group (length) per a single trait, a median of these variables were used in this thesis. Also, logarithmic transformation of the median variables was tested but the results of those analysis are not included in this study.

4.2 Data editing

Dogs with a missing or inaccurate birth year (seven observations) were excluded from the analyses. In addition, trials that were dated before August and after December were removed (two). There were also errors in the id numbers of the chief judges. These errors were assumed to be due to typos so the four chief judge numbers were corrected. Dogs with erroneous identities were excluded from the data (17 observations). Also, trials where the owner or handler had withdrawn from the trial, the dog had been barred or disqualified, the judge had interrupted the trial or incorrect points were given were removed from the data (totally 219 observations).

For efficiency, bark to hold, quality of bark, following, stopping, bark time, audibility, and frequency, only observations from full trials (where an elk was found) were considered, and blank trials (5705 observations in each trait) were set as missing. Also, if the dog had a blank trial the sub points for cooperation during work on game or after the trial time (5705 observations in each trait) were set as missing. After editing, the final data consisted of 23074 observations of 4392 dogs and 3645 trial events.

4.3 Distribution of hunting traits

Descriptive statistics

Elk was found in most of the trials (Table 4). Means of the traits varied between 4.24 and 9.02 in traits where the maximum points was ten. Phenotypic standard deviations were highest in bark related traits. Coefficients of variation were generally low. Highest coefficients of variation were for traits relating to ranging rounds. Also, obedience after trials had higher coefficient of variation than most of the traits. Stopping had the highest coefficient of variation within search and find traits.

Table 4. Descriptive statistics of the traits.

Trait	**N**	**μ**	**σ_P**	**CV**	**Min. value**	**Max. value**	**Unit**
Search and find traits							
Search	23 034	7.31	1.54	21.04	0	10	points
Efficiency	17 337	8.49	1.62	19.13	0	10	points
Following	17 337	9.02	1.83	20.22	0	10	points
Stopping	17 337	7.66	3.20	41.81	0	10	points
Bark traits							
Bark to hold	17 337	7.70	3.05	39.67	0	10	points
Quality of bark	17 337	7.35	3.15	42.85	0	10	points
Bark time	17 337	7.72	3.33	43.08	0	10	points
Audibility	17 337	8.34	2.77	33.19	0	10	points
Frequency	17 337	7.93	2.77	34.98	0	10	points
Obedience traits							
Obedience	23 034	4.24	2.38	56.07	0	10	points
Obedience during search	23 034	1.81	0.43	23.74	0	2	points
Obedience during work	17 337	2.12	1.65	78.03	0	5	points
Obedience after trial	17 337	1.11	1.05	94.84	0	3	points
Ranging rounds							
Circle – blank rounds	17 218	2.28	1.84	80.81	0.1	9.35	km
Time – blank rounds	17 145	27.13	21.41	78.93	1	101.5	min
Length – blank rounds	17 906	1.00	0.96	96.10	0.1	12	km
Circle – full rounds	16 510	2.37	2.02	84.96	0.1	9.9	km
Time – full rounds	16 285	25.08	20.85	83.13	1	95	min
Length – full rounds	17 095	1.16	1.02	87.46	0.1	9.1	km

The distribution of the total points is bimodal because maximum points of the blank trials is seventeen and full trials 100 (Figure 3). The last interval includes values from 95 to 100. The most common points are around 10 to 15 and 85 to 90.

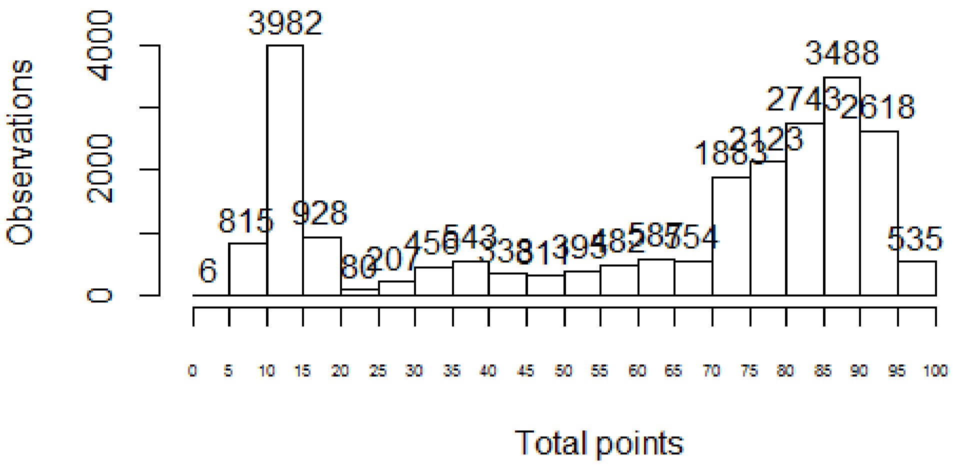
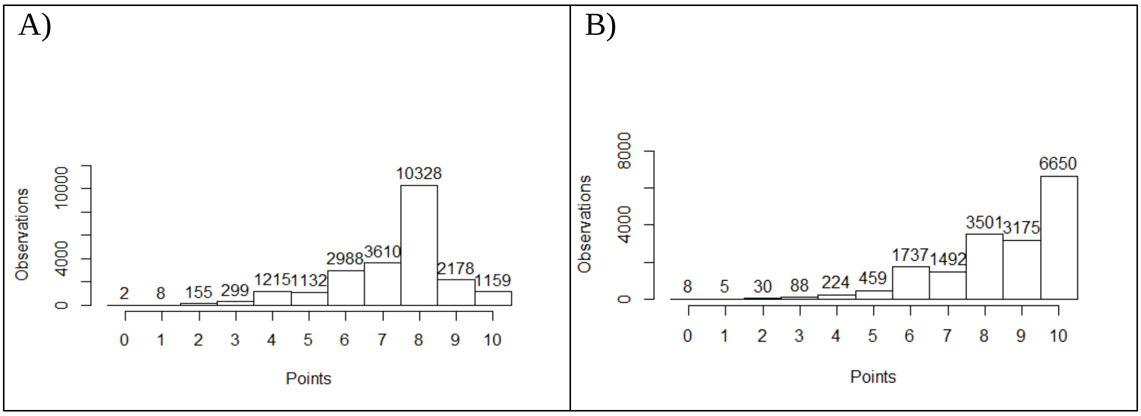


Figure 3. Distribution of total points.

Search and find traits

The distributions of points given for search and find traits are skewed to the right and the whole scale is seldom used (Figure 4). Ten points is frequently given with the exception of search where eight points is also common due to basis of evaluation (inadequately long circles give a maximum of eight points).



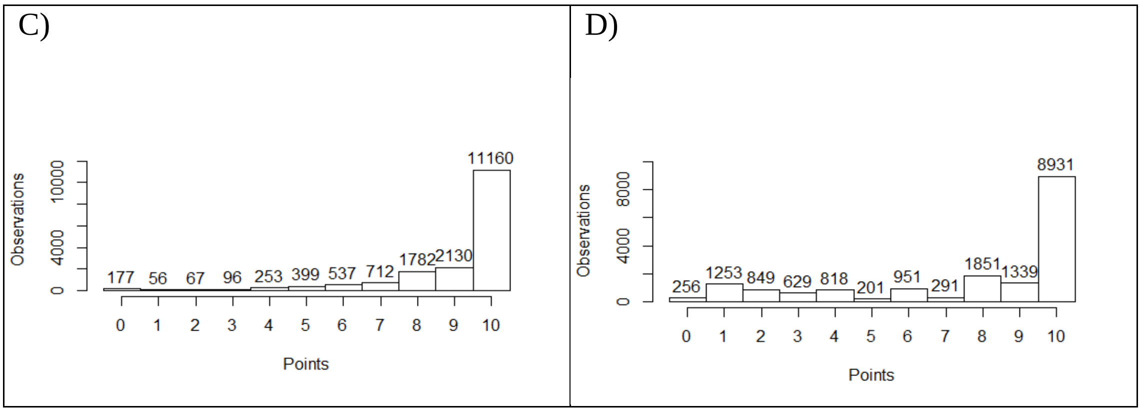
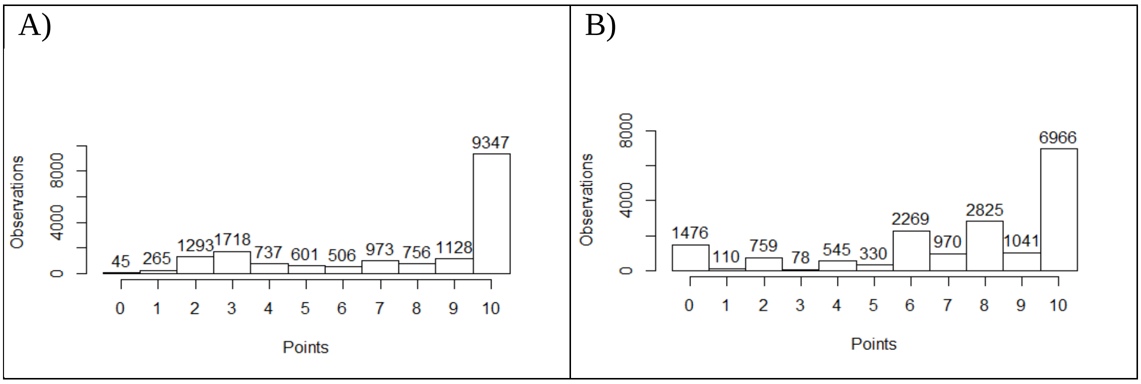


Figure 4. Distribution of points given in search (A), efficiency (B), following (C), and stopping (D).

Bark traits

Distribution of points given for bark traits is skewed to the right (Figure 5). Full scale is more often used for quality of bark than for the other bark traits. Zero appears to be in use more often than with search traits.

Maximum points are given for over 50 % of dogs for bark to hold, bark time, and audibility each. For quality of bark the whole scale of points appears to be in use though the mode is still in ten points. In audibility judges tend to give either ten or eight points, nine points is seldom given. There is clearly more variation in frequency and the distribution is more balanced compared to the others of bark related traits.



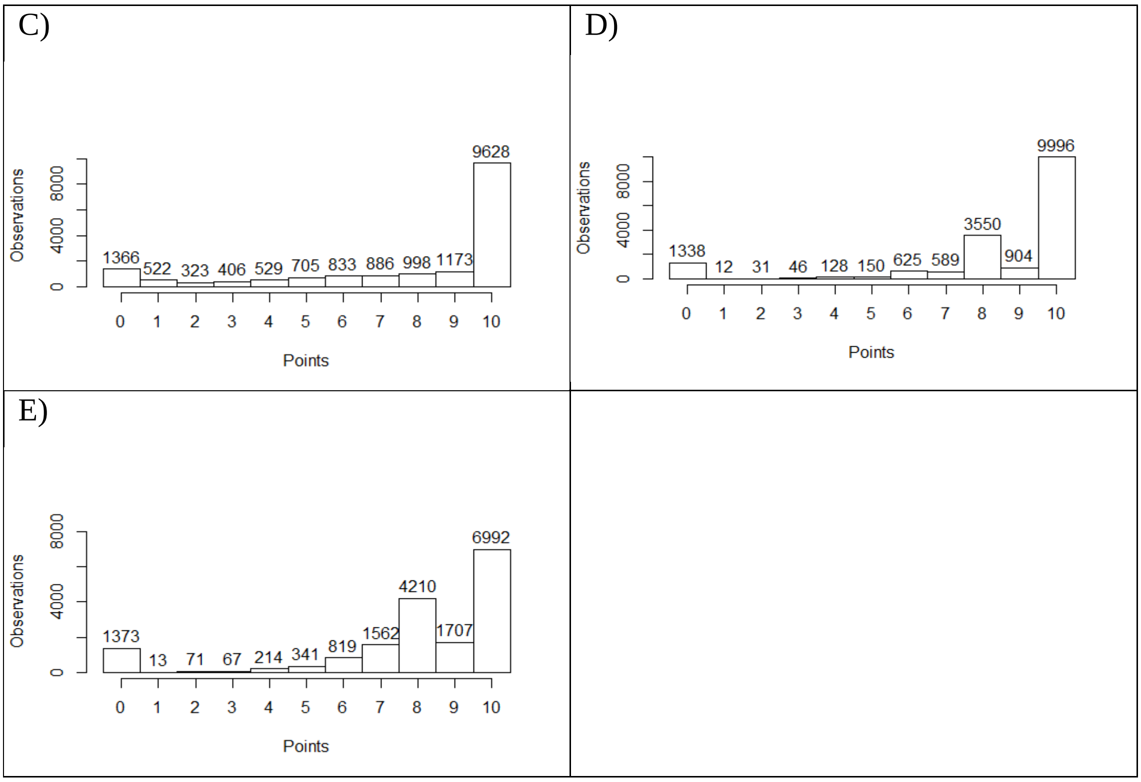


Figure 5. Distribution of points given in bark to hold (A), quality of bark (B), bark time (C), audibility (D), and frequency (E).

Obedience traits

Obedience was analyzed from both total points, and sub points given during search, working on game, and after the trial time (Figure 6). Distribution of points given for obedience in total is bimodal because the maximum points for obedience in blank trials is two. The whole scale is applied, and especially during elk work and after trial. A maximum of two points is frequently given in obedience during search, in both full and blank trials (Figure 6D–F). In blank trials points other than the maximum are practically never given. In full trials the distribution is rather balanced with mid values being commonly used, although, almost 80 percent of dogs receive the maximum of two points for obedience in full trials during search. In obedience after trial in full round there is evident skewness to the left but the whole scale of points is still in use. Minority of the dogs received maximum points.

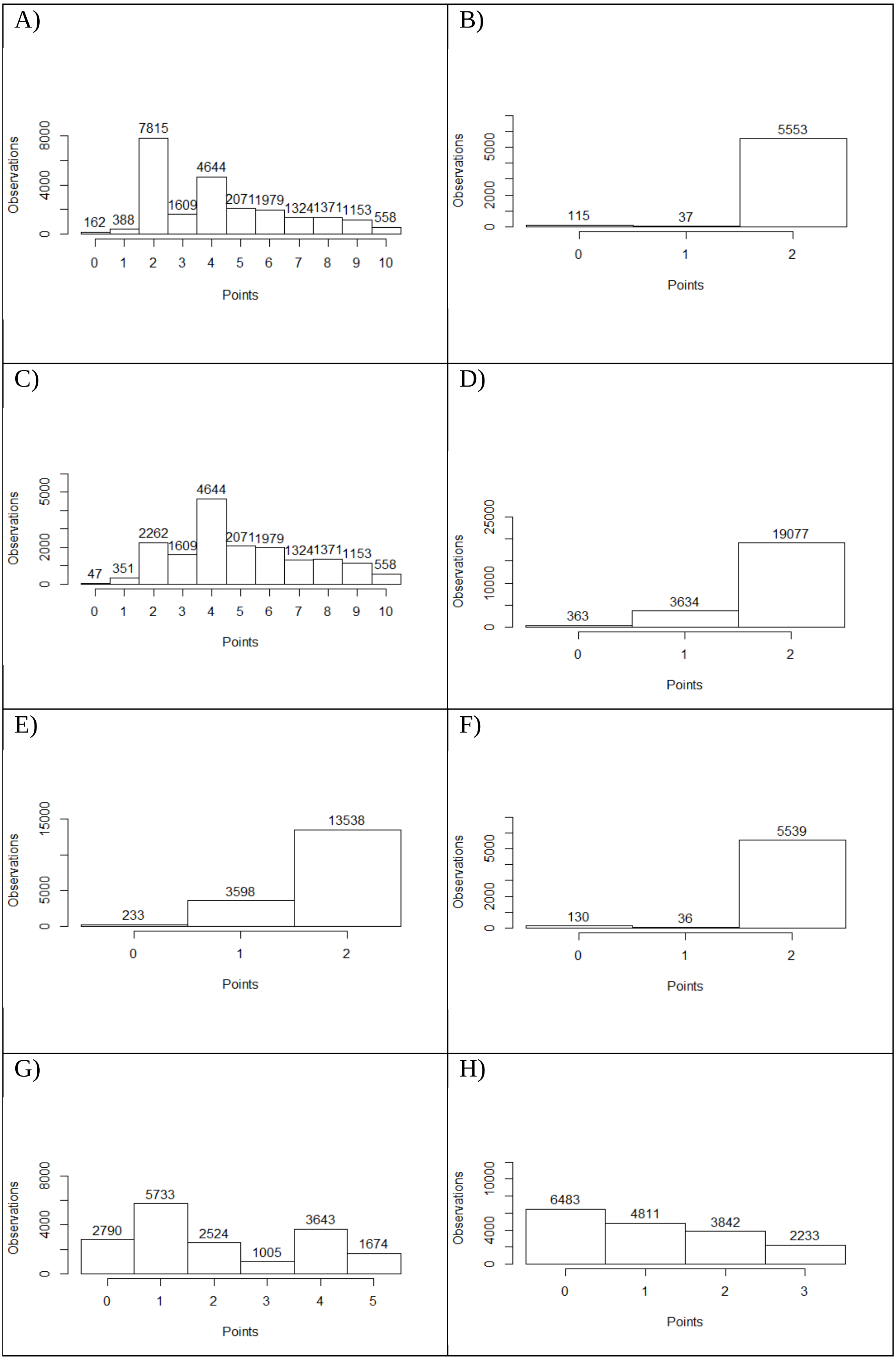


Figure 6. Distribution of points given in obedience (A), obedience in blank trials (B), obedience in full rounds (C), obedience during search (D), obedience during search in

full trials (E), obedience during search in blank trials (F), obedience during working an elk in full trials (G), and obedience after trial in full trials (H).

Ranging rounds

Observations of circles, times, and lengths of ranging rounds were based of median values of several ranging rounds. Even after excluding the observations that were three standard deviations apart from the mean, the distribution of these traits were still right skewed (Figure 7). The logarithmic transformations for the data on ranging rounds were also applied, but the results are not reported in this master’s thesis. Generally dogs make circles of a few kilometers and spend about a half an hour or an hour on them. Dogs tend to search for less than an hour, whether there is and elk to be found or not, and for less than three kilometers when they find an elk (Figure 7B). There are numerically more temporally longer ranging rounds in full rounds compared to the blank rounds. Length of a ranging round is generally less than two kilometers meaning that the group approaches the dog while it is on its ranging round.

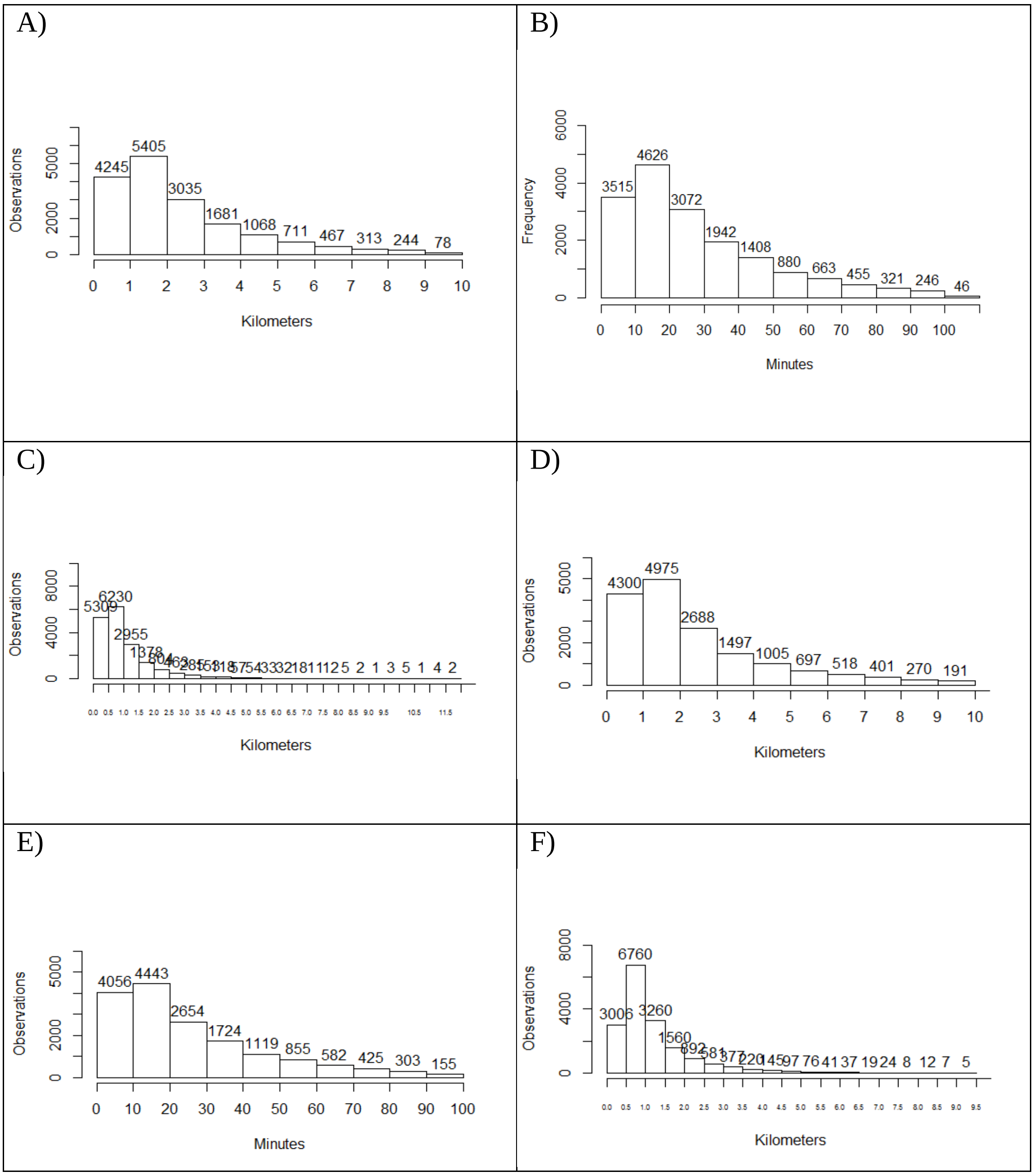


Figure 7. Distribution of points given in circle from ranging rounds in blank rounds (A), time of ranging rounds in blank rounds (B), length from ranging rounds in blank rounds (C), circle from ranging rounds in full rounds (D), time from ranging rounds in full rounds (E), and length from ranging rounds in full rounds (F).

4.3 Fixed effects and their classification

The data consisted of 12 614 observations of 2 424 males and 10 460 observations of 1 968 females. On average females had more observations than males (5.32 versus 5.20).

Age

The average age for a dog to attend a trial was 2.4 years. Dogs were divided into five age classes: under-two-year-old dogs were coded as “1”, two-year-old dogs were coded as “2”, three-year-old dogs were coded as “3”, four-year-old dogs were coded as “4”, and five-year-old or older dogs were coded as “5”. A dog may belong to several classes based on its age at the trial. Frequency distribution of age groups is given in Figure 8. Most dogs belonged to young age groups (less than three-year-olds) at the time of trial.

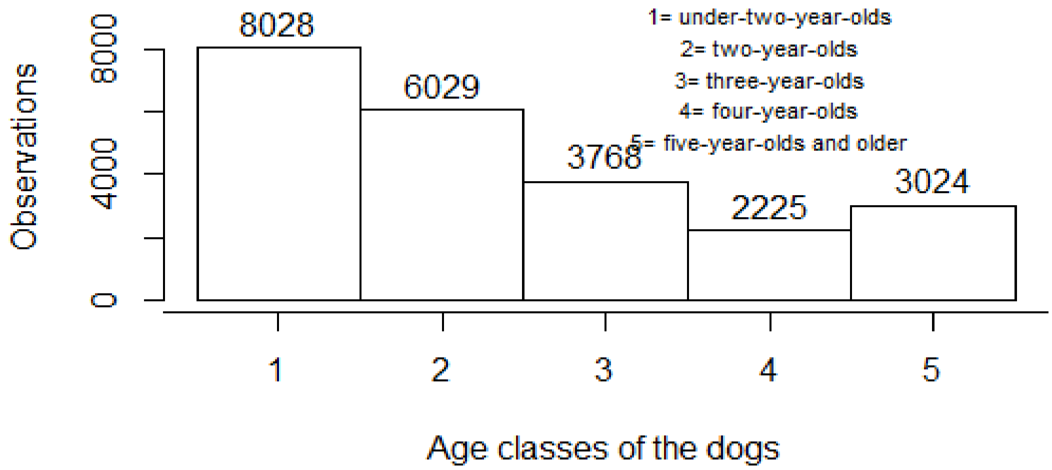


Figure 8. Distribution of the age classes.

Year, month and kennel district

The observations were recorded between 2012 and 2016. The average number of observations per year was 4 614 in the data. Annual frequencies of trial observations are given in Figure 9. In 2012, right after the new trial regulations were set, there were clearly less trials compared to subsequent years. Monthly variation in the number of trial observations varied between 3 701 and 8 321 (Figure 10). The most popular month to attend a trial was December (8 321 observations) and the lowest number of observations were from October (3701 observations). Observations from August (296 observations) were combined with observations from September because a low number of trials were taken on August.

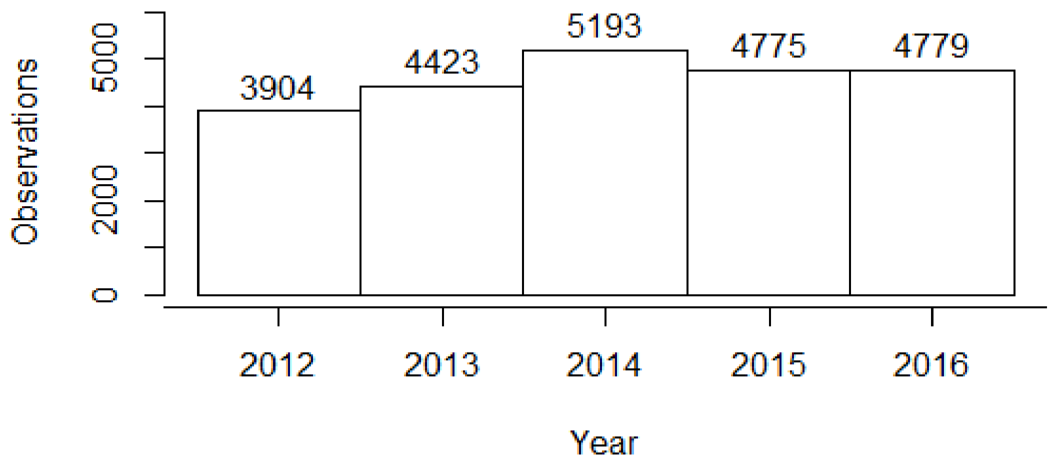


Figure 9. Distribution of observations by year.

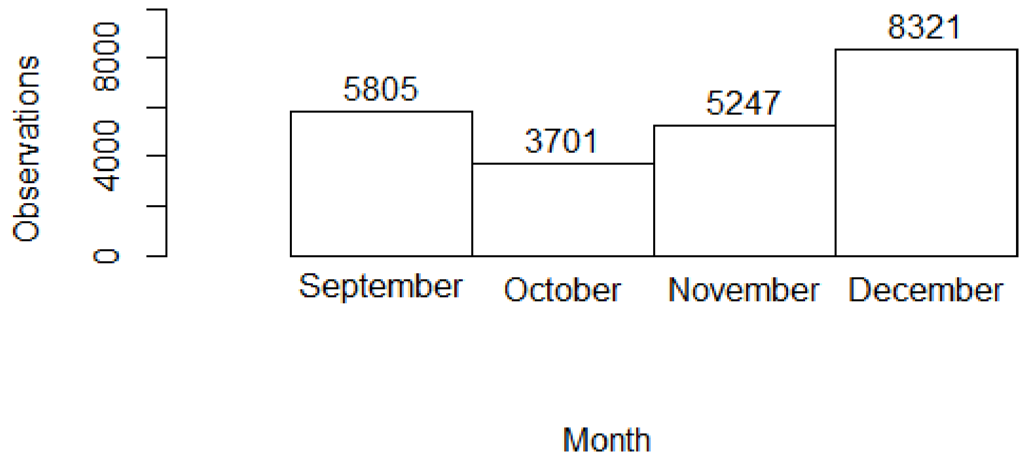


Figure 10. Distribution of observations by month.

There are 19 kennel districts in Finland (Figure 11) (SKL2017a). Kennel districts that had a low frequency of observations were combined based on their geographical location. Data from kennel districts of Tavastia Proper (kennel district number 1), Päijänne Tavastia (kennel district number 13), and Pirkanmaa (kennel district number 9) were combined (kennel district number 20). Observations from kennel districts in Southwest Finland (kennel district number 8), Helsinki (kennel district number 19), and Uusimaa (kennel district number 16) were combined (kennel district number 21). The observations from Åland Islands were discarded for their low frequency and for their exceptional geographical location. This led to a reduction of 16 observations from the data.

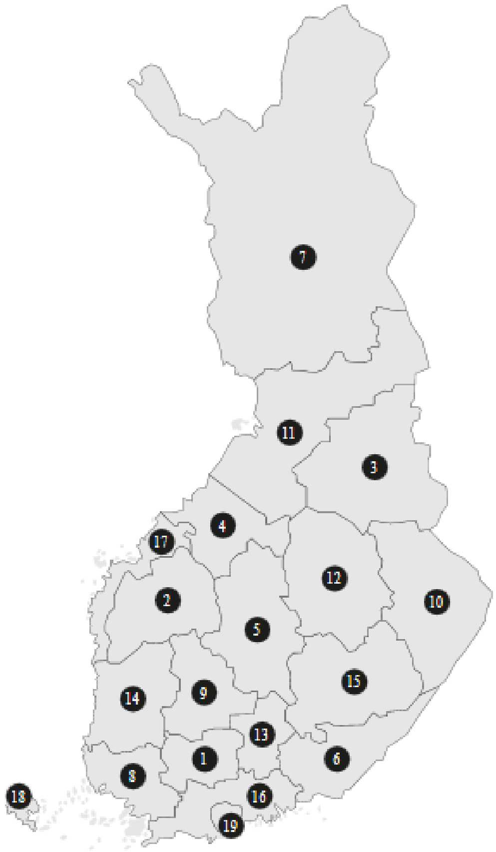


Figure 11. Kennel districts in Finland. https://www.kennelliitto.fi/yhteystiedot/muut-yhteystiedot/kennelpiirit

The average number of observations per kennel district was 1648 varying from 467 to 2854, the highest number of observations per kennel district being in Southern Ostrobothnia. The number of observations in each kennel district for the data is given in Figure 12.

A year*month*kennel district -variable was created in order to take areal and seasonal variation into account in the analysis. The *year*month*kenneldistrict -variable divided the observations into 280 classes. The maximum number of observations (339) was in class “20161202” relating to December, 2016 of the Southern Ostrobothnia kennel district. The minimum number of observations (eight) was class “20121017”.

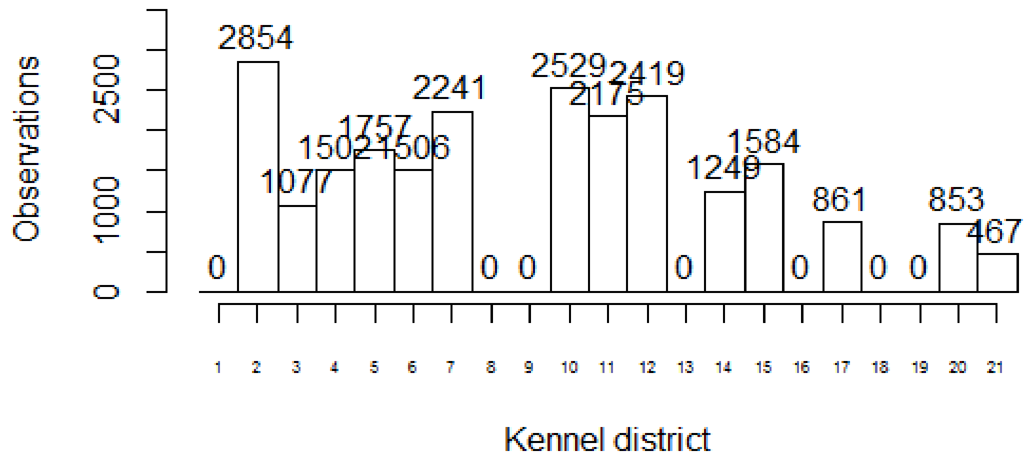


Figure 12. Number of observations in kennel districts (after combining the kennel districts).

Trial type

Two variables to separate trial types were created: general vs championship trial and regular vs long trial. The rules and regulations regarding the evaluation are the same for general trials and national championship trials (Jukka Immonen, personal communication) but it is possible that the trial type has a direct effect on judging the trial and an indirect effect on the dog's performance at the trial. The national championship trials were coded as 2 (128 observations), and the general trial as 1.

In long trials fields are not randomly assigned and the dog may carry the trial out in a familiar terrain, thus possibly affecting the dog's performance. Long trials were coded as 2, and the regular trials as 1. There were 7 387 long trials (32 %) and 15 687 (68 %) regular trials in the data.

Snow situation

A slight snow blanket may help the dog locating the game so a snow -variable was created to depict the snow situation at the trial. If the snow blanket at the trial was equal or greater than one centimeter the trial was considered as being held on snow blanket and the snow situation at the trial was coded as 2. Bare ground was coded as 1. Most trials, 14 387 (62 %), were set up on bare ground, and 8 687 (38 %) were set up on snow blanket.

Experience and elk finding

In order to create a experience –variable dogs were divided into four classes based on the number of observations per dog in the data. First class consisted of dogs with only one observation, the second class included the dogs with two to five observations, the third class included the dogs with six to ten observations, and dogs with more than ten observations were included in the fourth class. Most of the dogs had more than one but less than six observations. The number of observations in each class is shown in Figure 13.

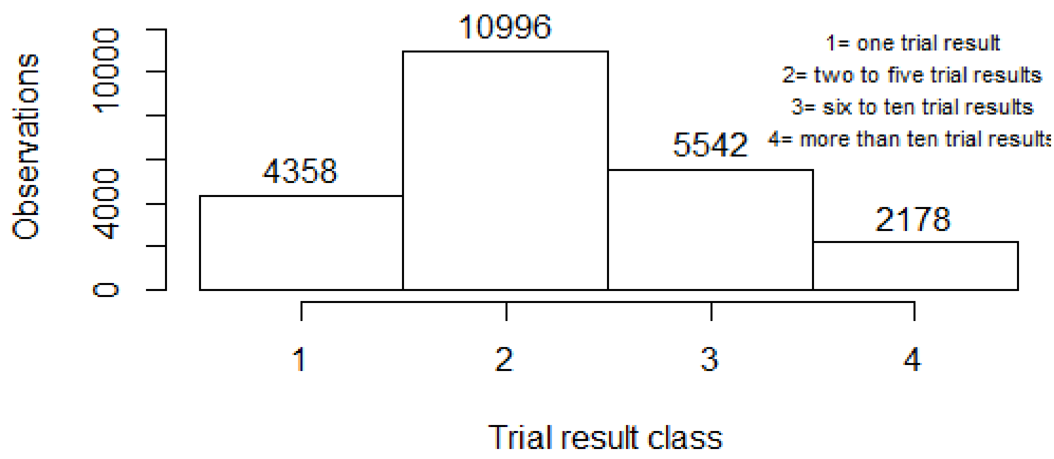


Figure 13. Distribution of observations in different experience-classes.

An elk find –variable was created to separate full and blank trials from each other. If the dog had a contact with an elk during the trial (had one or more full rounds) the variable was coded as 2, and otherwise as 1. Out of the 23 074 trials 17 369 (75.3 %) were with an elk find rounds and 5 705 (24.7 %) were blank.

4.4 Random effects and their classification

Four random effects were included into a statistical model: litter, chief judge, permanent environmental and animal effect (breeding value).

Litter

The dogs were given a litter-ID based on their dam, sire, and birth date. The dogs in the data were from 1 584 litters. The maximum number of observations per litter was 128. The maximum number of dogs from the same litter that had attended trials was 13.

Chief judge

There were 362 individual chief judges in the trials in the data (Table 5). The average number of trials evaluated by a judge was 63.7. The maximum number of trials evaluated per judge was 355.

Table 5. Number of trials judged by an individual judge.

Trials judged	0–10	11–50	51–100	101–200	201–
Number of judges	90	109	75	73	15

The pedigree data

The pedigree data of Jämthunds registered in Finland was received from the Finnish Kennel Club. The data included information of the registration number, sex, birth date, and registration number of the sire and of the dam of 31 544 individual Jämthunds. Of these dogs, 535 were removed from the data because of missing parental information and eight dogs because of false parental information.

The pedigree was pruned to 6446 animals that had either observations or were tied to dogs with observations through ancestry (down to four generations).

4.6 Linear models

In addition to overall mean the initial model included seven fixed effects: age, sex, snow, year*month*kenneldistrict, championship, trial type, and experience. For search, obedience, and obedience during the search also elk find was included in the model. The final model for each trait was constructed through backward selection without random effects in RStudio 1.1.136 (RStudio Team 2016). The significance of the effects of the final model was tested with ANOVA and are given in Tables 6–10.

Table 6. Significance of the fixed effects on search and find traits.

Search and find traits	Search	Efficiency	Following	Stopping
Year*month*kennel district	***	***	ns	ns
Championship	ns	ns	ns	*
Sex	***	***	***	***
Snow	ns	***	***	***
Trial	***	**	ns	***
Elk	***	na	na	na
Age	***	***	ns	ns
Experience	***	***	***	***

*** (p<0.001), ** (p< 0.01), * (p<0.05), ns=non-significant, na=not applicable

Table 7. Significance of the fixed effects on bark traits.

Bark traits	Bark to hold	Quality of bark	Bark time	Audibility	Frequency
Year*month*kennel district	***	***	***	***	***
Championship	ns	ns	ns	ns	ns
Sex	***	***	***	***	ns
Snow	***	***	***	***	***
Trial	***	***	***	***	***
Age	*	ns	ns	ns	ns
Experience	***	***	***	***	***

*** (p<0.001), ** (p< 0.01), * (p<0.05), ns=non-significant

Table 8. Significance of the fixed effects on obedience traits.

Obedience traits	Obedience	Obedience during search	Obedience during work	Obedience after trial
Year*month*kennel district	ns	ns	***	ns
Championship	***	ns	ns	***
Sex	ns	***	**	***
Snow	***	***	***	***
Trial	***	***	***	***
Elk	***	***	na	ns
Age	*	ns	**	ns
Experience	***	*	***	***

*** (p<0.001), ** (p< 0.01), * (p<0.05), ns=non-significant, na=not applicable

Table 9. Significance of the fixed effects on circle, time, and length of the blank ranging rounds.

Blank rounds	Circle	Time	Length
Year*month*kennel district	***	***	ns
Championship	ns	ns	ns
Sex	***	ns	***
Snow	***	***	***
Trial	*	ns	ns
Age	***	ns	***
Experience	***	***	***

*** (p<0.001), ** (p< 0.01), * (p<0.05), ns=non-significant

Table 10. Significance of the fixed effects on circle, time, and length of the full ranging rounds.

Full rounds	Circle	Time	Length
Year*month*kennel district	ns	ns	ns
Championship	ns	ns	ns
Sex	***	***	***
Snow	***	***	***
Trial	***	***	***
Age	***	***	***
Experience	***	**	*

*** ($p<0.001$), ** ($p< 0.01$), * ($p<0.05$), ns=non-significant

The final models used in variance component estimation included also chief judge, litter, permanent environmental, and animal as random effects. Chief judge was treated as a random effect because of large number of chief judges and some of them had a limited number of observations. A repeatability animal model was used because 3461 (78.8 %) of the dogs had multiple observations (mean of the observations per a dog was 5.25). The maximum number of observations per an individual dog in the limited data was 40.

Variance components and correlations were estimated using the AI-REML approach (Patterson and Thompson 1971) in the DMU software package (version 6, release 5.2, Madsen & Jensen 2013).

In general, each model was of the form $\mathbf{y = Xb + Kj + Ll + Wpe + Za + e}$,

where

$\mathbf{y}$ = a vector of observations

$\mathbf{b}$ = a vector of fixed effects

$\mathbf{j}$ = a vector of the judge effects

$\mathbf{l}$ = a vector of the litter effects

$\mathbf{pe}$ = a vector of permanent environmental effects

$\mathbf{a}$ = a vector of random animal effects

e = a vector of random residual effects

X, K, L, W and **Z** are the matrices that relate to corresponding fixed and random effects.

It was assumed that random effects are normally distributed with expected values of 0 and var(j)=$\mathbf{I}\sigma_j^2$, var(l)=$\mathbf{I}\sigma_l^2$, var(pe)=$\mathbf{I}\sigma_{pe}^2$, and var(a)=$\mathbf{A}\sigma_a^2$, and var(e)=$\mathbf{I}\sigma_e^2$, where **I** is a diagonal matrix and **A** is the additive relationship matrix between the animals. Corresponding variances of judge, litter, permanent environment, animal (additive genetic component) and residual effects are σ_j^2, σ_l^2 , σ_{pe}^2, σ_a^2, and σ_e^2, respectively.

Heritability was calculated as $h^2 = \sigma_a^2/\sigma_P^2$, where σ_a^2 is the additive genetic variance and σ_P^2 is the phenotypic variance ($\sigma_P^2 = \sigma_j^2 + \sigma_l^2 + \sigma_{pe}^2 + \sigma_a^2 + \sigma_e^2$). Repeatability was calculated as r = $(\sigma_a^2 + \sigma_{pe}^2)/\sigma_P^2$. Standard errors of the heritabilities and correlations were based on Taylor series approximation.

Correlation between the traits were based on two-trait model with **A** $\otimes$ **G,** where $\otimes$ is the Kronecker product of the two matrices in two-trait analysis and **G** is a 2 by 2 matrix of additive genetic variances of the traits in the diagonal and covariances between the traits in the off-diagonals.

In the two-trait model the effects of judge and litter were left out of the analyses since their effect was marginal**.** For ranging rounds, only circles were analyzed since time is connected to the circle (and to the speed of the dog) and length is affected by how much the group itself proceeds (which varies indirectly).

5 RESULTS

5.1 Fixed effects

Age

Older dogs tend to search better and received more points in efficiency (Table 11). Younger dogs, as well as rather matured dogs, were more obedient in general and older dogs received better points in obedience during work. Older dogs performed better in bark to hold. Under-two-year-olds and the oldest dogs got the highest points in obedience. Oldest dogs also performed the best in obedience during work. Age was significant on all traits considering full rounds, but on blank rounds only on circle and length, not on time of the ranging round. Youngest dogs made shorter rounds and spent least time on ranging rounds, except for the circle from blank rounds, where dogs of age four made shorter rounds than dogs at the age of three.

Table 11. Effect of age expressed as deviations from group 5 (five-year-old or older dogs).

Age groups	**1**	**2**	**3**	**4**
Search and find traits				
Search	-0.23 (0.05)	-0.18 (0.04)	-0.09 (0.04)	-0.07 (0.04)
Efficiency	-0.18 (0.05)	-0.15 (0.05)	-0.13 (0.05)	-0.12 (0.05)
Obedience traits				
Obedience	0.01 (0.04)	-0.04 (0.04)	-0.01 (0.04)	-0.09 (0.05)
Obedience during work	-0.03 (0.03)	-0.04 (0.03)	-0.02 (0.03)	-0.09 (0.04)
Bark traits				
Bark to hold	-0.24 (0.09)	-0.15 (0.09)	-0.16 (0.09)	-0.26 (0.01)
Blank rounds				
Circle	-0.23 (0.06)	-0.19 (0.06)	-0.08 (0.06)	-0.14 (0.06)
Length	-0.08 (0.03)	-0.07 (0.03)	-0.03 (0.03)	-0.03 (0.03)
Full rounds				
Circle	-0.34 (0.06)	-0.22 (0.06)	-0.19 (0.06)	-0.12 (0.07)
Time	-3.12 (0.64)	-2.17 (0.62)	-1.90 (0.64)	-1.67 (0.71)
Length	-0.13 (0.03)	-0.08 (0.03)	-0.04 (0.03)	-0.03 (0.03)

Groups: 1: under two-year-old dogs, 2: two-year-old dogs, 3: three-year-old dogs, 4: four-year-old dogs.

Sex

Sex had a significant effect (p=0.001) on all the traits except obedience and time on blank rounds (p=0.1), and obedience during work (p=0.01) (Table 12). Sex had no significant effect on frequency. Generally, males performed better than females, except for obedience during search. Males made longer ranging rounds, but were faster on blank rounds than females.

Table 12. Effect of sex (males vs females).

Sex			
Search and find traits			
Search	0.18 (0.03)	Efficiency	0.22 (0.03)
Following	0.11 (0.03)	Stopping	0.50 (0.06)
Bark traits			
Bark to hold	0.51 (0.05)	Quality of bark	0.69 (0.06)
Bark time	0.68 (0.06)	Audibility	0.50 (0.05)
Obedience traits			
Obedience	0.07 (0.03)	Obedience during search	-0.04 (0.01)
Obedience during work	0.06 (0.02)	Obedience after	0.09 (0.02)
Blank rounds			
Circle	0.12 (0.04)	Time	-0.61 (0.40)
Length	0.11 (0.02)		
Full rounds			
Circle	0.21 (0.03)	Time	1.27 (0.36)
Length	0.11 (0.02)		

Snow

In general dogs performed better on snow blanket than on bare ground (Table 13). However, dogs got a bit better points for following and made shorter and faster ranging rounds on bare ground compared to snow covered ground.

Table 13. Effect of snow (bare ground vs snow blanket).

Snow			
Search and find traits			
Efficiency	-0.08 (0.025)	Following	0.063 (0.028)
Stopping	-0.38 (0.049)		
Bark traits			
Bark to hold	-0.58 (0.05)	Quality of bark	-0.47 (0.05)
Bark time	-0.47 (0.05)	Audibility	-0.56 (0.04)
Frequency	-0.55 (0.04)		
Obedience traits			
Obedience	-2.70 (0.02)	Obedience during search	-0.02 (0.01)
Obedience during work	-2.40 (0.02)	Obedience after trial	-0.29 (0.02)
Blank rounds			
Circle	0.26 (0.03)	Time	4.97 (0.34)
Length	0.13 (0.02)		
Full rounds			
Circle	0.09 (0.03)	Time	1.30 (0.33)
Length	0.06 (0.02)		

Year, month, and kennel district

The year*month*kenneldistrict –variable had a large number of classes so only some examples of the estimates are presented. In figures 14 and 15 the differences in estimates of the year*month*kenneldistrict for two of the largest kennel districts Southern Ostrobothnia (02) and North Karelia (10) for two separate traits – search and circle from blank rounds are presented. Independent on year and month the points for search were higher in Southern Ostrobothnia than in North Karelia (Figure 14). No systematic differences between these two kennel districts were obtained in circle from blank ranging rounds (Figure 15).

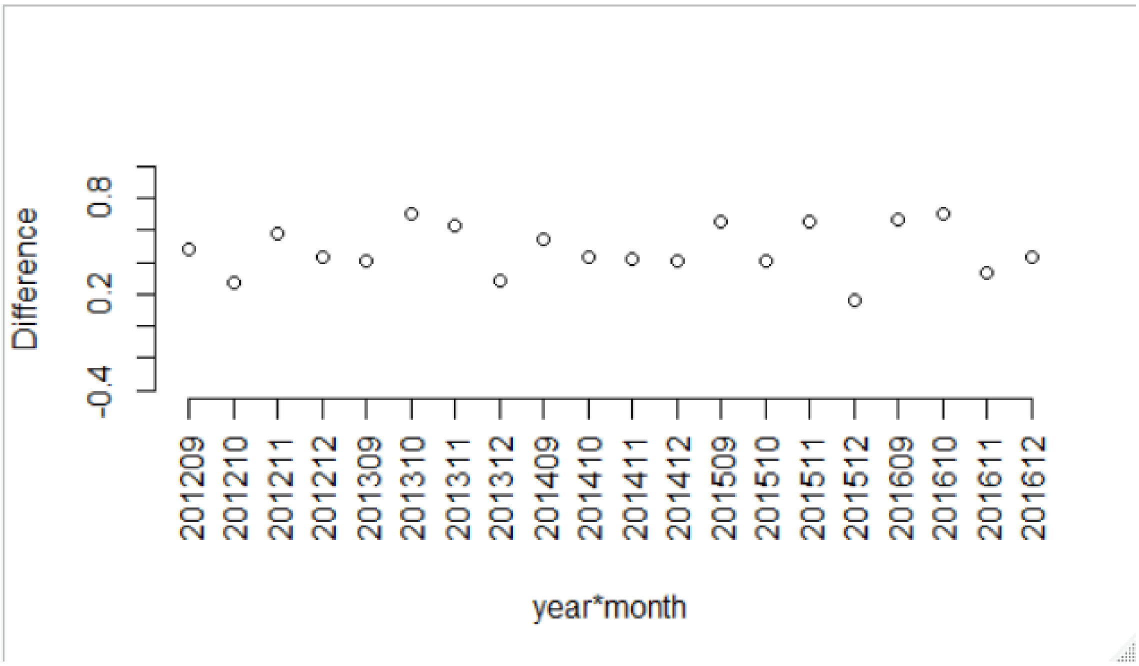


Figure 14. Differences between the estimates of year*month*kenneldistrict –variable on search for Southern Ostrobothnia and North Karelia kennel districts.

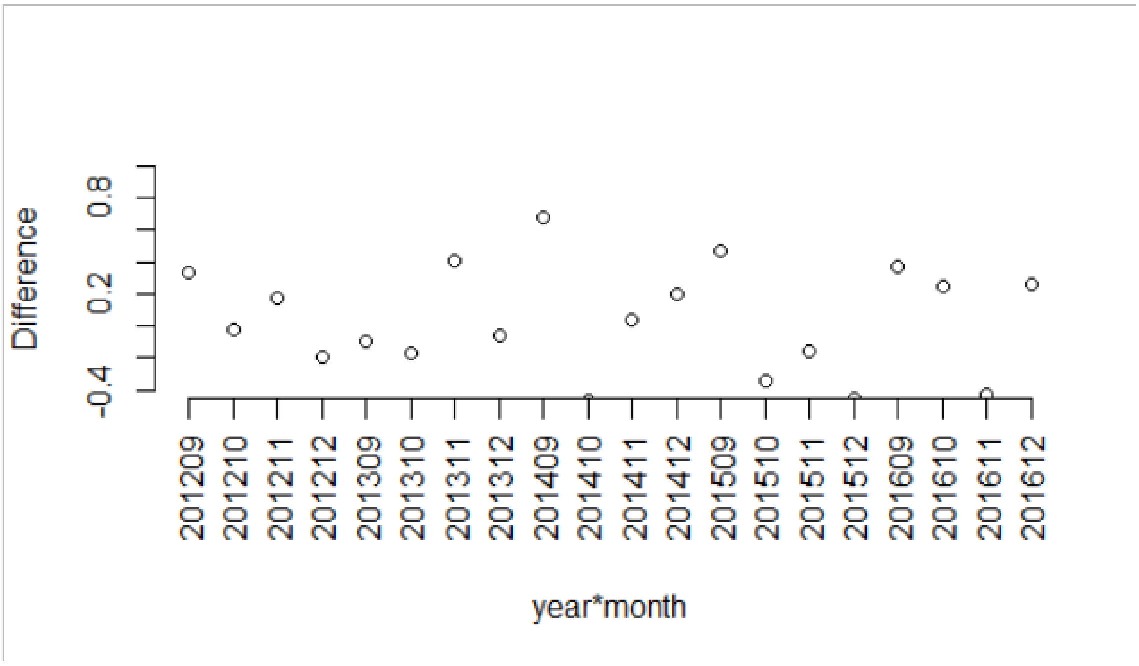


Figure 15. Differences between the estimates of year*month*kenneldistrict –variable on circle from blank rounds for Southern Ostrobothnia and North Karelia kennel districts.

Trial type

Dogs performed better in long trials except for obedience during search (Table 14). Full rounds in regular trials took more time, and circles and lengths were longer than in long trials. Circle from blank rounds was shorter for the regular trials.

Table 14. Effect of trial (regular vs long trial).

Trial type			
Search and find traits			
Search	-0.36 (0.03)	Efficiency	-0.27 (0.03)
Stopping	-0.73 (0.06)		
Bark traits			
Bark to hold	-0.68 (0.06)	Quality of bark	-0.72 (0.06)
Bark time	-0.74 (0.06)	Audibility	-0.60 (0.05)
Frequency	-0.64 (0.05)		
Obedience traits			
Obedience	-0.22 (0.03)	Obedience during search	0.04 (0.01)
Obedience during work	-0.16 (0.02)	Obedience after	-0.17 (0.02)
Blank rounds			
Circle	-0.24 (0.04)		
Full rounds			
Circle	0.19 (0.04)	Time	3.05 (0.39)
Length	0.09 (0.02)		

Championship trials

Estimated difference between general trial and championship trial was significant only on obedience after trial. Dogs performed better in championships trials than in general trials: dogs in championship trials got 0.19±0.10 points more than dogs in general trials.

Experience and elk finding

Dogs performed better when they had more experience (Table 15). In ranging rounds dogs with more experience made longer circles with more time and length than the dogs with less experience with the exception of time in full rounds where dogs with six to ten observations took slightly more time to make the rounds. Elk find had a significant effect on search, obedience, and obedience during search: dogs that had found an elk got

0.06±0.02 points more on search, and 1.66±0.03 points more on obedience, and 0.19±0.01 points less on obedience during search than dogs that did not find elk.

Table 15. Effect of experience as deviations from group 4 (more than ten observations).

Experience	**1**	**2**	**3**
Search and find traits			
Search	-0.51 (0.05)	-0.25(0.05)	-0.05 (0.04)
Efficiency	-0.52 (0.06)	-0.28(0.05)	-0.11 (0.05)
Following	-0.42 (0.06)	-0.23(0.05)	-0.06 (0.05)
Stopping	-1.09 (0.11)	-0.47(0.09)	-0.21 (0.10)
Bark traits			
Bark to hold	-0.42 (0.12)	-0.20(0.10)	-0.09 (0.10)
Quality of bark	-1.07 (0.11)	-0.51(0.10)	-0.21 (0.10)
Bark time	-1.07 (0.12)	-0.53(0.10)	-0.26 (0.10)
Audibility	-0.93 (0.10)	-0.43(0.09)	-0.21 (0.08)
Frequency	-0.97 (0.10)	-0.53(0.09)	-0.29 (0.09)
Obedience traits			
Obedience	-0.30 (0.05)	-0.16 (0.04)	-0.10 (0.04)
Obedience during search	0.01 (0.01)	0.00 (0.01)	-0.01 (0.01)
Obedience during work	-0.20 (0.04)	-0.11 (0.04)	-0.07 (0.04)
Obedience after	-0.23 (0.04)	-0.11 (0.03)	-0.06 (0.03)
Blank rounds			
Circle	-0.48 (0.07)	-0.28 (0.06)	-0.12 (0.06)
Time	-1.65 (0.76)	-0.90 (0.68)	-0.11 (0.68)
Length	-0.26 (0.03)	-0.17 (0.03)	-0.08 (0.03)
Full rounds			
Circle	-0.39 (0.07)	-0.28 (0.06)	-0.11 (0.06)
Time	-1.06 (0.75)	-1.16 (0.65)	0.18 (0.65)
Length	-0.08 (0.04)	-0.06 (0.03)	-0.02 (0.03)

Groups: 1: one observation, 2: two to five observations, 3: six to ten observations.

Estimates of the random effects are given in appendix 2.

5.3 Heritabilities and repeatabilities

The number of dogs (N), and estimates of the variances components are given in Tables 16–20. Also, the heritabilities (h^2) and repeatabilities (r) and their standard errors (se_h^2 and se_r) are presented. In general the estimated heritabilities were low, and varied from zero for obedience during work to 0.047 for search. Standard errors of heritabilities varied from 0.006 to 0.010. Repeatabilities varied from 0.015 to 0.032, and their standard errors varied from 0.008 to 0.013. The variance components of litter and the chief judge were low for all traits.

Search and find traits

The estimated heritabilities varied from 0.014 for efficiency to 0.047 for search. Standard errors of heritabilities varied from 0.006 to 0.010. Repeatabilities varied from 0.052 to 0.146, and their standard errors varied from 0.010 to 0.013. The highest repeatability was estimated for search.

Table 16. Estimates of variance components for search and find traits.

Trait	N	σ_e^2	σ_{pe}^2	σ_a^2	σ_j^2	σ_l^2	h^2 (se_h^2)	r (se_r)
Search	4 368	1.901	0.226	0.107	0.029	0.010	0.047 (0.010)	0.146 (0.013)
Efficiency	4 033	2.338	0.141	0.035	0.029	0.000	0.014 (0.006)	0.069 (0.010)
Following	4 033	2.975	0.251	0.067	0.010	0.020	0.020 (0.007)	0.096 (0.011)
Stopping	4 033	9.428	0.322	0.203	0.072	0.043	0.020 (0.006)	0.052 (0.010)

Bark traits

The estimated heritabilities were low, and varied from 0.009 for bark to hold to 0.033 for frequency. Standard errors of heritabilities varied from 0.005 to 0.009. Repeatabilities varied from 0.046 to 0.085 and their standard errors were low. The highest repeatability was estimated for frequency.

Table 17. Estimates of genetic parameters for bark traits.

Trait	N	σ_e^2	σ_{pe}^2	σ_a^2	σ_j^2	σ_l^2	h^2 (se_{h^2})	r (se_r)
Bark to hold	4 033	8.408	0.359	0.082	0.041	0.023	0.009 (0.005)	0.049 (0.009)
Quality of bark	4 033	8.790	0.482	0.199	0.039	0.032	0.021 (0.007)	0.071 (0.010)
Bark time	4 033	9.927	0.444	0.198	0.054	0.020	0.019 (0.006)	0.060 (0.010)
Audibility	4 033	6.948	0.250	0.087	0.033	0.012	0.012 (0.005)	0.046 (0.009)
Frequency	4 033	6.647	0.386	0.247	0.029	0.107	0.033 (0.009)	0.085 (0.012)

Obedience traits

For the obedience traits the estimated heritabilities were extremely low and close to zero. Highest heritability was estimated for obedience after trial (0.012). Standard errors of heritabilities were generally high, with the exception of the standard error of the heritability of obedience (0.004). Repeatabilities varied from 0.047 to 0.077 and their standard errors were low.

Table 18. Estimates of genetic parameters for obedience traits.

Trait	N	σ_e^2	σ_{pe}^2	σ_a^2	σ_j^2	σ_l^2	h^2 (se_{h^2})	r (se_r)
Obedience	4 368	2.251	0.158	0.017	0.024	0.005	0.007 (0.004)	0.071 (0.008)
Obedience during search	4 368	0.168	0.008	0.000	0.001	0.000	0.003 (0.005)	0.047 (0.008)
Obedience during work	4 033	1.109	0.070	0.000	0.016	0.007	0.000 (0.000)	0.059 (0.008)
Obedience after trial	4 033	0.975	0.069	0.013	0.008	0.000	0.012 (0.006)	0.077 (0.010)

Blank rounds

For blank rounds the estimated heritabilities varied from 0.036 to 0.041. Highest heritability was for time. Standard errors of heritabilities varied from 0.009 to 0.01. Repeatabilities varied only a little, from 0.100 to 0.113 and their standard errors were low.

Table 19. Estimates of genetic parameters for blank rounds.

Trait	N	σ_e^2	σ_{pe}^2	σ_a^2	σ_j^2	σ_l^2	h^2 (se_{h^2})	r (se_r)
Circle	4 078	2.885	0.250	0.123	0.005	0.028	0.037 (0.010)	0.113 (0.014)
Time	4 063	389.256	34.245	18.361	0.537	1.114	0.041 (0.010)	0.119 (0.014)
Length	4 113	0.814	0.058	0.033	0.006	0.001	0.036 (0.009)	0.100 (0.012)

Full rounds

In full rounds the estimated heritabilities were extremely low and varied from 0.008 to 0.0012. Highest heritability was for time. Standard errors of heritabilities were relatively high and varied from 0.004 to 0.005. Repeatabilities barely varied, being 0.032 – 0.034 and their standard errors were low.

Table 20. Estimates of genetic parameters for full rounds.

Trait	N	σ_e^2	σ_{pe}^2	σ_a^2	σ_j^2	σ_l^2	h^2 (se_{h^2})	r (se_r)
Circle	3 975	3.837	0.106	0.031	0.023	0.002	0.008 (0.004)	0.034 (0.008)
Time	3 948	411.674	8.814	5.224	2.042	1.423	0.012 (0.005)	0.033 (0.009)
Length	4 010	0.998	0.025	0.008	0.014	0.000	0.008 (0.004)	0.032 (0.008)

5.4 Genetic and phenotypic correlations

The genetic correlations varied from very weak negative to very strong positive. Correlations are given in Tables 21–24, phenotypic correlations below diagonal and genetic correlations above diagonal. Full table of genetic and phenotypic correlations is given in appendix 3.

Search and find traits

The genetic correlation varied between 0.25 and 0.91 within search and find traits. There was a very strong positive genetic correlation between efficiency and search. Search had a weak genetic correlation with quality of bark and very weak genetic correlation with frequency. Standard errors of genetic correlations were generally low except for traits related to following and frequency. Phenotypic correlations were all weak, excluding the phenotypic correlation between search and efficiency.

Table 21. Correlations of search and find traits. Genetic correlations and their standard errors (in parentheses) in the upper diagonal and phenotypic correlations in the lower diagonal.

Trait	**Search**	**Efficiency**	**Following**	**Stopping**	**Quality of bark**	**Frequency**
Search	1	0.91 (0.07)	0.34 (0.16)	0.47 (0.14)	0.41 (0.15)	0.05 (0.14)
Efficiency	0.43	1	0.25 (0.20)	0.58 (0.20)	na	na
Following	0.09	0.14	1	0.73 (0.15)	0.73 (0.20)	0.28 (0.17)
Stopping	0.08	0.13	0.25	1	na	na
Quality of bark	0.09	na	0.20	na	1	na
Frequency	0.10	na	0.12	na	na	1

na=not applicable

Bark traits

Genetic correlations between different bark traits varied from moderate to very strong. Quality of bark and audibility had a very strong positive genetic correlation. Frequency was moderately correlated with bark to hold, quality of bark, and audibility, and weakly correlated with bark time. The genetic correlation between bark time and quality of bark was 1.0. Standard errors of the genetic correlations were very low. Phenotypic correlations were from moderate to very strong.

Table 22. Correlations of bark traits. Genetic correlations and their standard errors (in parentheses) in the upper diagonal and phenotypic correlations in the lower.

Trait	**Bark to hold**	**Quality of bark**	**Bark time**	**Audibility**	**Frequency**	**Stopping**
Bark to hold	1	0.83 (0.10)	0.85 (0.11)	0.79 (0.12)	0.55 (0.15)	na
Quality of bark	0.60	1	1.00 (0.04)	0.98 (0.03)	0.56 (0.11)	na
Bark time	0.58	0.95	1	0.96 (0.03)	0.49 (0.12)	0.97 (0.02)
Audibility	0.57	0.83	0.84	1	0.51 (0.12)	0.94 (0.05)
Frequency	0.55	0.77	0.77	0.87	1	na
Stopping	na	na	0.89	0.74	na	1

na=not applicable

Obedience traits

There was a very strong positive genetic correlation between obedience during search and obedience during work. Obedience after trial had weak or moderate genetic correlations with obedience during search and obedience during work, and the phenotypic correlations varied from weak negative to weak positive. Standard errors were relatively high.

Table 23. Correlations of obedience traits. Genetic correlations and their standard errors (in parentheses) in the upper diagonal and phenotypic correlations in the lower.

Trait	**Obedience**	**Obedience during search**	**Obedience during work**	**Obedience after trial**
Obedience	1	0.73 (0.27)	0.88 (0.14)	0.75 (0.12)
Obedience during search	0.19	1	0.93 (0.65)	0.27 (0.33)
Obedience during work	0.77	-0.03	1	0.61 (0.31)
Obedience after trial	0.74	-0.04	0.38	1

Ranging rounds

Table 24. Correlations of ranging rounds. Genetic correlations and their standard errors (in parentheses) in the upper diagonal and phenotypic correlations in the lower.

Trait	**Search**	**Bark to hold**	**Obedience**	**Circle blank**	**Circle full**
Search	1	0.38 (0.19)	0.14 (0.21)	0.94 (0.04)	0.77 (0.12)
Bark to hold	0.09	1	0.24 (0.30)	0.24 (0.21)	0.40 (0.25)
Obedience	0.03	0.23	1	-0.27 (0.21)	-0.25 (0.27)
Circle blank	0.41	0.01	-0.02	1	0.83 (0.13)
Circle full	0.21	0.06	0.00	0.12	1

Search had a very strong positive genetic correlation with blank circles, and full circles. Blank and full circles were strongly correlated with each other. The genetic correlation between bark to hold and full circles was weak. Standard errors of genetic correlations were relatively high, with the exception of the genetic correlation between search and circles. The phenotypic correlations between the traits were very weak, with the exception of the genetic correlation between blank circles and search.

5.5 Inbreeding

The pedigree data including 29 183 animal was used to analyze the coefficient of inbreeding. The average coefficient of inbreeding by birth years between 1970 and 2016 is presented in Figure 16. As can be seen from the figure there has been several peaks where the coefficient of inbreeding has been relatively high. For dogs born in 2016, the average coefficient of inbreeding was 7.03 %. The maximum average coefficient of inbreeding was for dogs born in 1993 (9.50 %). The coefficient of inbreeding has decreased 0.26 % between 2006 and 2016.

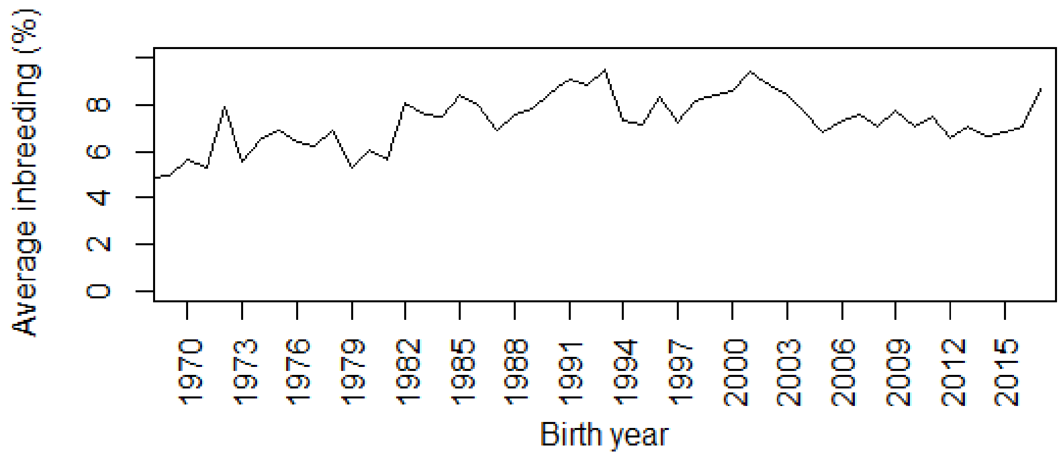


Figure 16. Average coefficient of inbreeding by birth years.

5.6 Genetic trends

Genetic trends are presented using standardized indices (mean 100 and standard deviation of 10) using the estimated breeding values of the dogs born between 2012 and 2016, and having two or more observations.

Search and find traits

The genetic trends for search and find traits have been positive with only little fluctuation (Figure 17). During the years 2006-2016 search and find traits have improved approximately by 10 index points (1 SD).

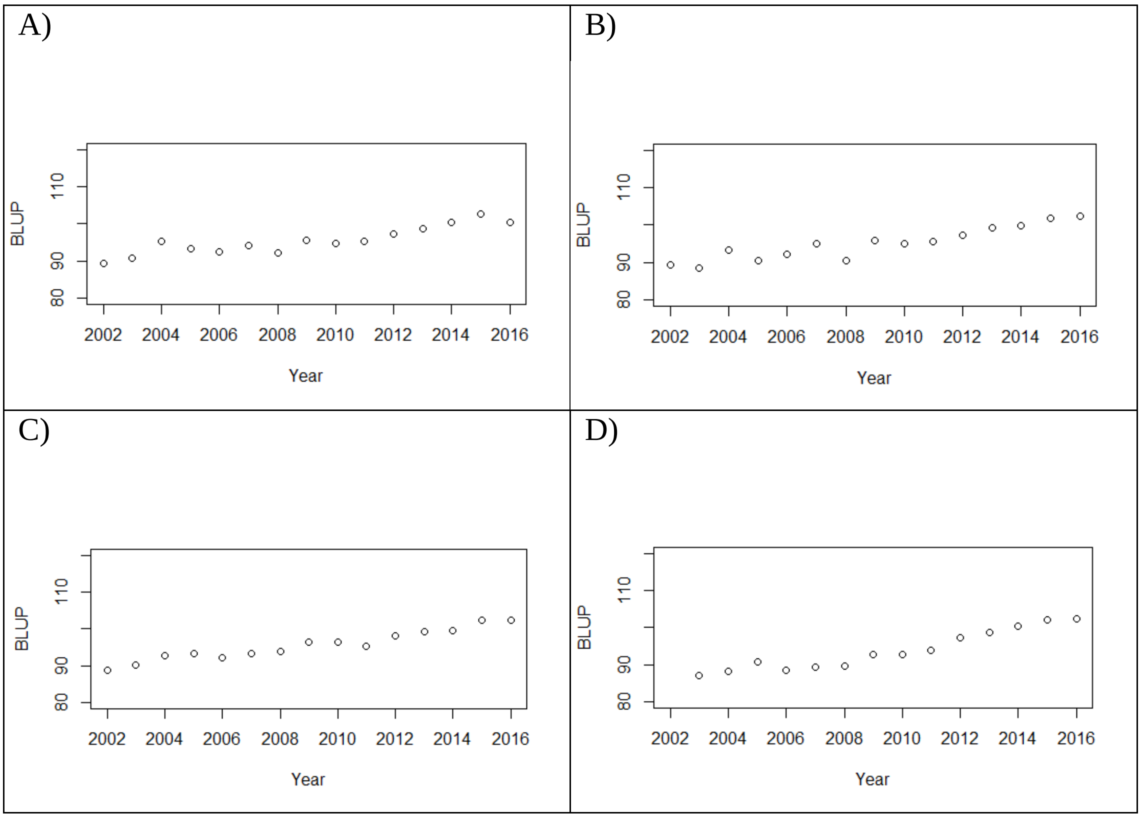
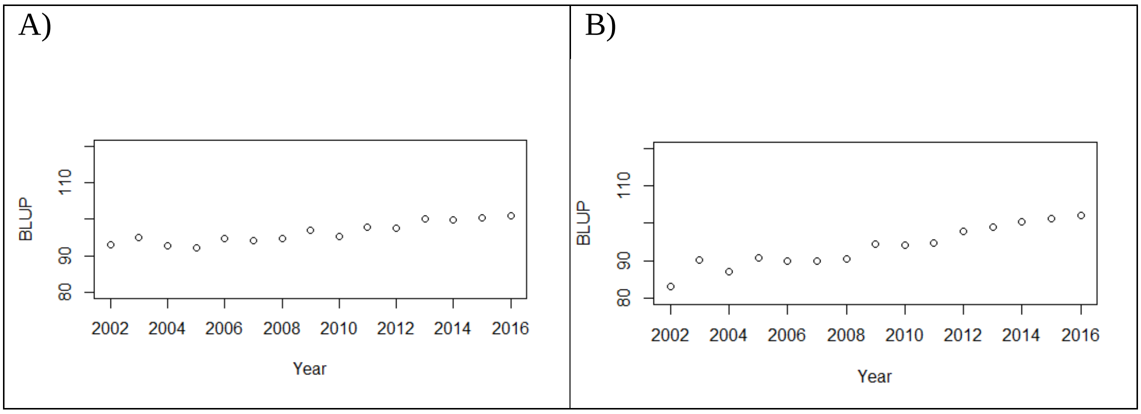


Figure 17. Genetic trends for A) search, B) efficiency, C) following, and D) stopping by birth year.

Bark traits

The genetic trends for bark traits have been generally positive with only a little fluctuation (Figure 18). The genetic improvement of the quality of bark has been a little slower than for the other traits.



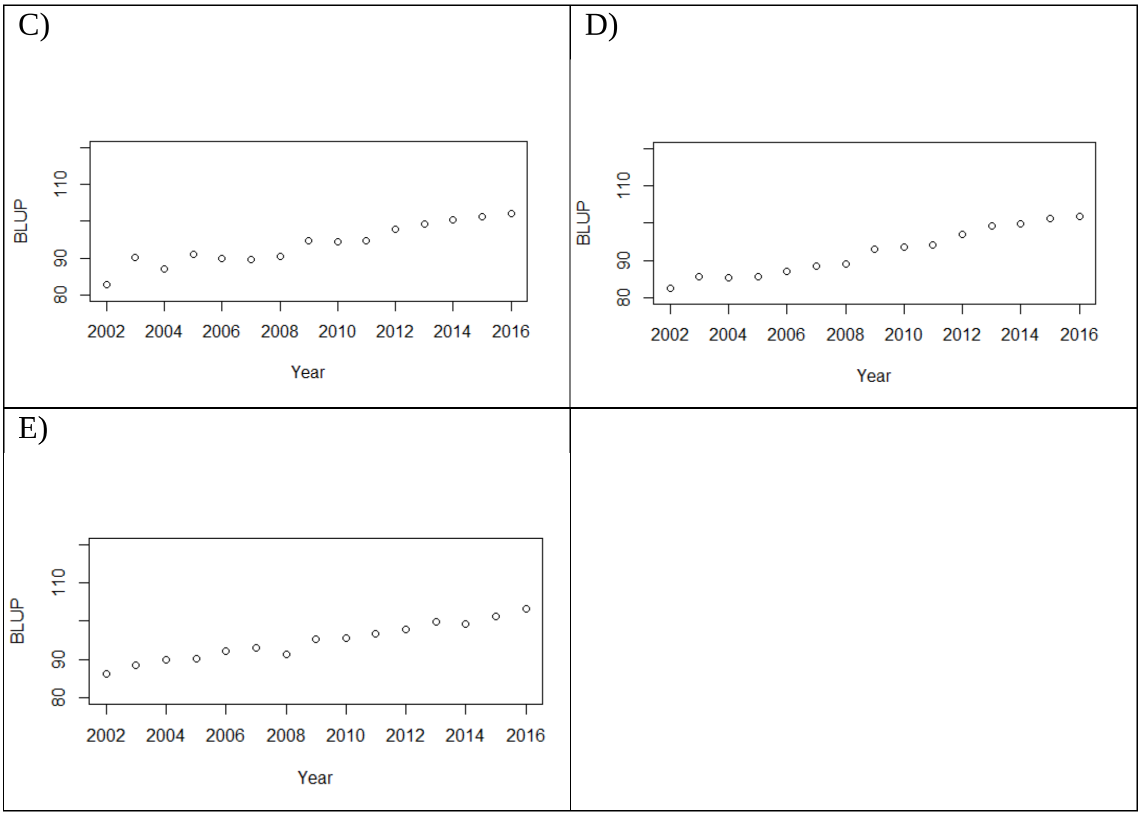
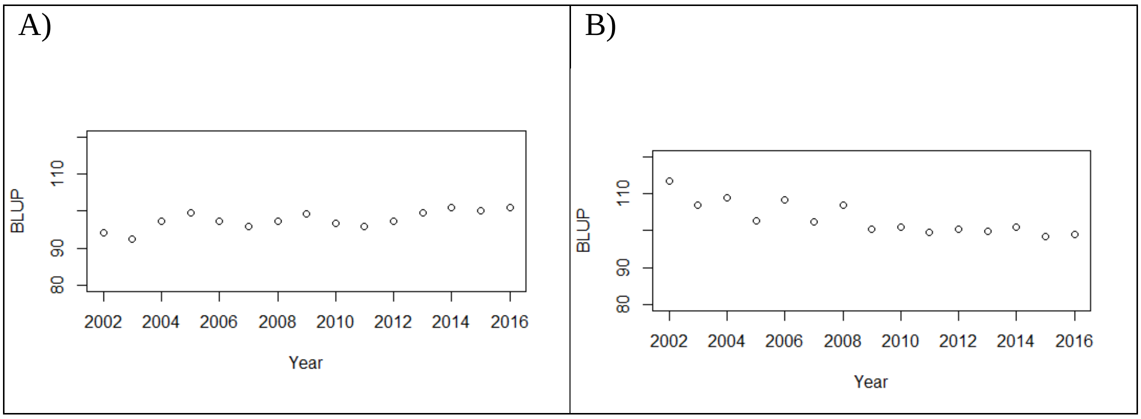


Figure 18. Genetic trends for A) bark to hold, B) quality of bark, C) bark time, D) audibility, and E) frequency by birth year.

Obedience traits

The genetic improvement of the obedience traits has been slow, and for obedience during search the genetic trend has actually been negative (Figure 19). There is plenty of fluctuation in the mean of the annual BLUP-estimates.



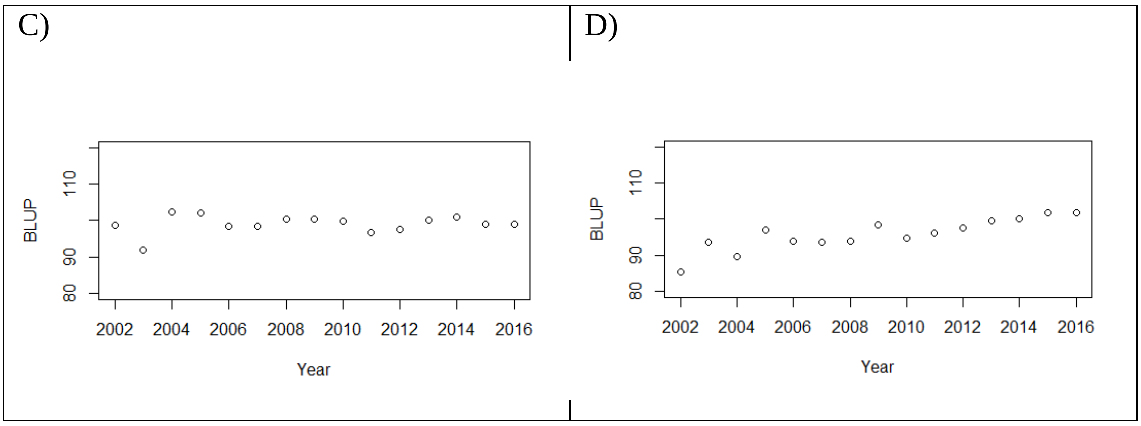


Figure 19. Genetic trends for A) obedience, B) obedience during search, C) obedience during work, and D) obedience after trial by birth year.

Circle, time, and length of the ranging rounds

The genetic trends for circle from blank and full ranging rounds have been positive and rather fast with only a little fluctuation, and rather fast especially for circle and time of the ranging round (Figure 20–21).

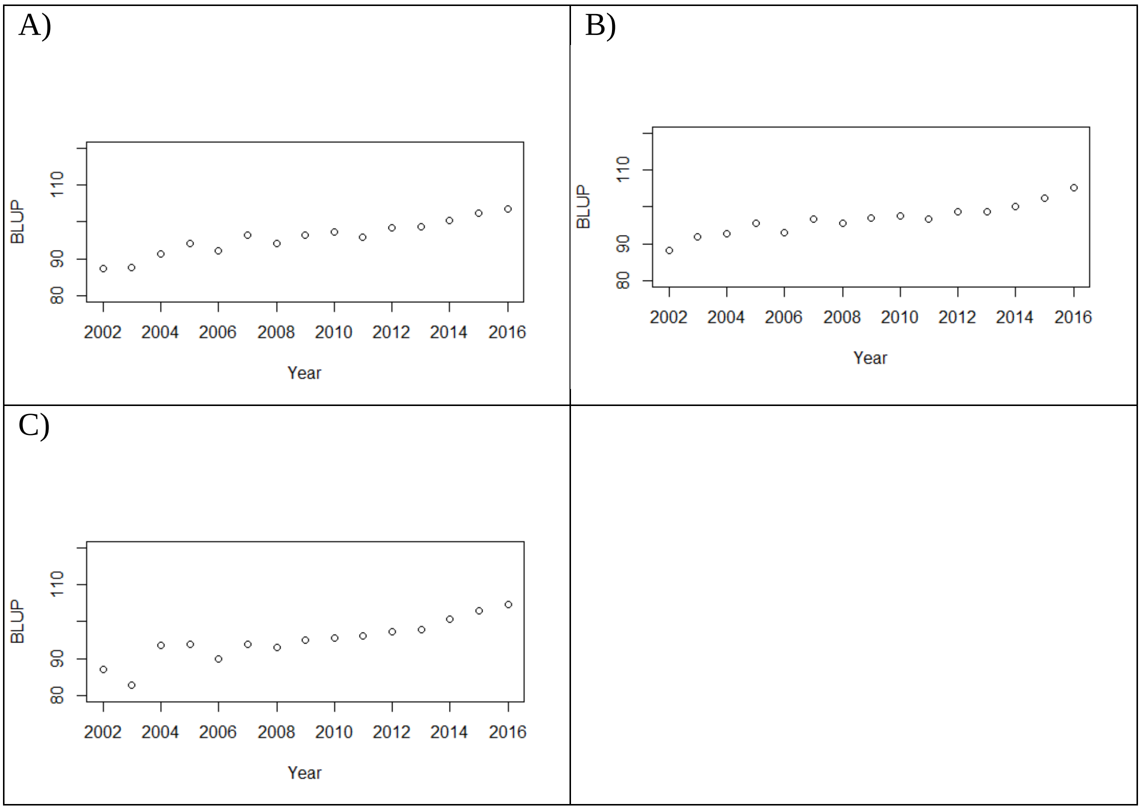


Figure 20. Genetic trends for A) circle (blank rounds), B) time (blank rounds), and C) length (blank rounds) by birth year.

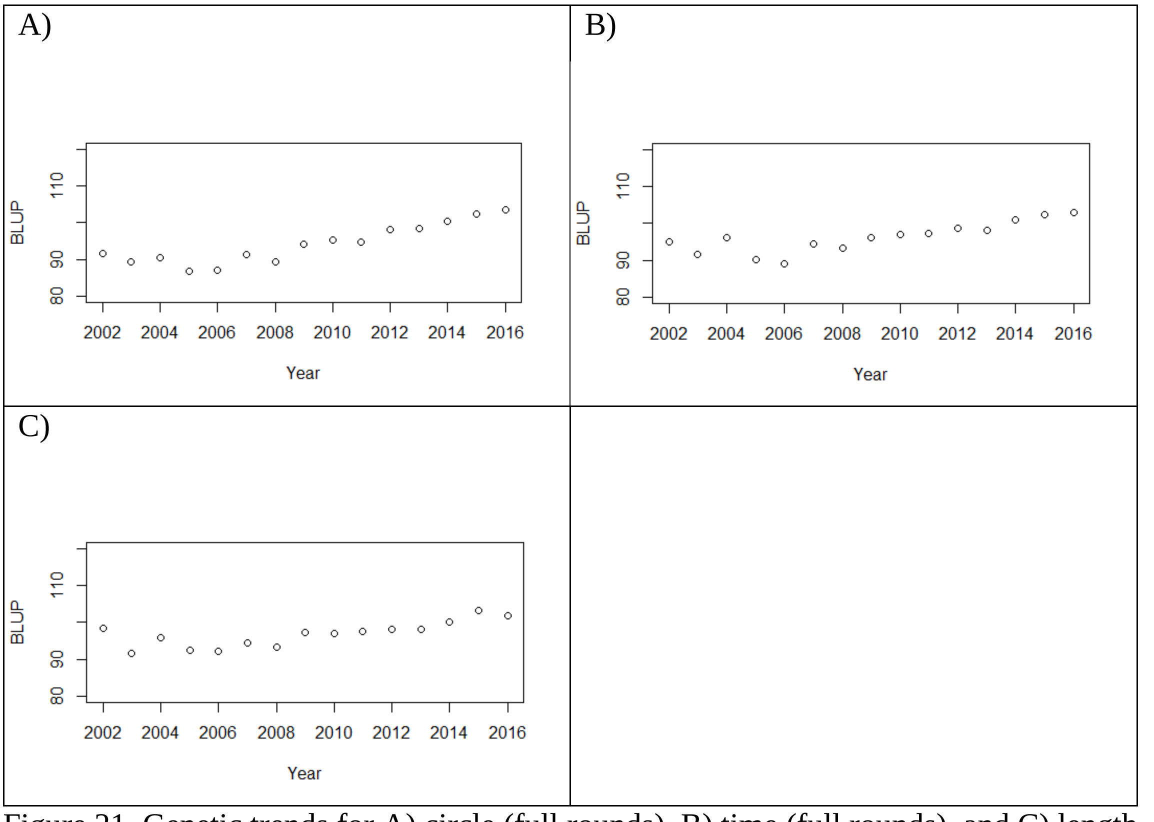


Figure 21. Genetic trends for A) circle (full rounds), B) time (full rounds), and C) length (full rounds) by birth year.

6 DISCUSSION

The objective of the current study was to estimate heritabilities and genetic correlations of the hunting traits of the Jämthund. Overall the heritabilities were low but genetic correlations between the traits were high. Even though the heritabilities were low they were reliable given the small standard errors of the estimates. Below possible factors affecting the results and recommendation to improve data collection of hunting traits are discussed.

6.1 Size, structure, and quality of the data

The final data included 23074 observations of 4392 dogs. The pedigree data included 6446 animals including animals with records and their ancestors down to four generations. Both phenotypic data and pedigree data were large enough for reliable genetic analyses.

Logarithmic transformation was used for circle, time, and length of the ranging rounds but the effect of the transformation on results was insignificant. The genetic parameters were also estimated using only the first observation of each dog but the results were similar to results estimated using the repeatability animal model.

The whole scale of points was seldom used which caused the distributions of traits being skewed. Breed-specific scaling could be advantageous regarding the rules and regulations of the elk hunting trials.

6.2 Statistical model and methods

A linear mixed model was applied with several fixed effects and chief judge, litter, permanent environmental and animal as random effects. The fixed effects were generated based on the information collected during the trial. Some of the fixed effects, such as type of the trial (long vs regular), were straight forward to create but for some fixed effects such as snow coverage were more ambiguous and could have been classified in several ways. In this thesis two classes were used for snow coverage but more classes or a numerical variable could have been used. Similarly some kennel districts were combined because of small number of trials. The division into kennel districts may still be too vague and creates environmental variation. In this study, dogs were divided into experience classes based on the number of observations in the data. This may have caused bias in analyses because a dog with plenty of experience but with only one observation between 2012 and 2016 is assigned to a class with inexperienced dogs. The whole trial history of the dog should be taken into account.

In order to improve breeding value estimation, some possible important systematic effects were missing in the current recording system and data. For example, weather conditions, especially wind and rain, should be recorded and their effect on hunting traits analyzed. In addition, the type of terrain the trial takes place should be recorded. Although the kennel district takes some of this variation into consideration, there is yet variation between terrains within kennel district. Open field versus dense forest creates different type of conditions for hunting. The age and sex of the elk found should also be recorded, since it has an effect on the behavior of the elk, thus generating different type of conditions for following and stopping the elk. Physical status of the dog could also be recorded and the youngest age class divided to two: dogs between nine months and one year and from one year to two years.

6.3 Fixed and random effects

The effect of age on search and efficiency were significant, older dogs got higher points than younger ones. This is expected because older dogs may have more experience on finding elk and may have a better ability to separate between old and new trails of the elks, and direction where the elk has run. On bark traits age had an effect only on bark to hold; dogs between two to three years of age got better points compared to one or four-year-olds. However, oldest dogs (five years or more) got the highest points. The results are similar with the results by Liinamo et al. (1997). Bark to hold may be correlated with dog's courage and self-confidence, and so it gets better with age and through experience. Older dogs are also more matured and may have received more thus being more obedient than younger dogs. The standard errors of estimate of age effect on obedience traits were high in this study and the results cannot be considered reliable. The subjectivity of the evaluation may cause undesirable random variation in results that cannot be modelled. Considering ranging rounds, it is possible that young dogs are somewhat less independent on their owner, tend to make shorter and less efficient ranging rounds, and so receive fewer points in search and efficiency as well. Younger dogs are expected to have better physical stamina compared to senior dogs, so it is likely that the difference is explained by mental abilities.

Sex had a significant effect on most of the traits and the standard errors of the estimated were low (except for time of the blank ranging rounds). Females were more obedient during search maybe because females tend to be more sensitive or soft and willing to please the owner. Sensitivity towards owner often gets lower when the drive gets higher. This may explain why differences between sexes is small in obedience during work. The large difference between the sexes in bark traits and stopping may be due to males having a stronger tone in their voice and they may also be more courageous in confronting the elk. The effect of sex on bark traits was opposite of those presented by Karjalainen et al. (1996), but consistent with those by Liinamo et al. (1997). The difference between the sexes was small in following, thus better performance of the males in stopping and elk may be due to their better bark traits. Opposite to my results, Liinamo et al. (1997) found that females performed better in following than males. Males performed better than females in search in this study as well as the in studies by Liinamo et al. (1997) and Karjalainen et al. (1996). Here, as well, it is possible that the independency of the dog is correlated to how well the dog works, and males may be more independent from their owner and that way perform better in search.

Dogs' better performance in long trials in most traits may be explained by the fact that in long trial the dog likely works in a familiar environment and the owner is usually well aware of where and how many elk are at the area. In a long trial, full rounds tend to be shorter which supports this assumption.

Snow was significant for all traits except search points. A reason why snow did not have an effect on search points could be that the judge already takes the snow blanket in account when giving the points for search since the effect of the snow blanket on dog's performance is generally known. Generally better points were received on snow except following was easier on bare ground. The effect of snow on bark traits and following in this study are opposite to those of Liinamo et al. (1997) and Karjalainen et al. (1996). These previous studies had bird dogs and hounds, so the behavior of the game can explain the different results.

Finding an elk or not had an effect on search and obedience. Dogs that did not find an elk got lower points in search and obedience, but higher points in obedience during search than dogs that found an elk. When a dog finds an elk it is possible that the search behavior is more evident to be judged.

The effect of judge on hunting traits was marginal in this study, opposite to Arvelius and Klemetsdal (2013). All conditions taken into account when giving points during the trial that are not recorded creates bias through extensive quantity of judges. When heritabilities are estimated the data could be limited to observations judged by only those judges that have more than for example a hundred trials judged. This would remove subjectivity to some point when the number of judges would decrease and the experience of the judges would increase.

The litter effect was also small in all traits, and thus time before weaning is not important for hunting traits. Since litters of the same parents (repeated mating) are usually reared under same conditions by the same breeder, repeated matings could be considered as one litter in the genetic analyses. Thus instead of using litter effect, a breeder effect can be used giving more observations per group. Owner of the dog and the experience of the owner also influence on the traits and their effect should be estimated.

6.4 Heritabilities

The heritabilities and repeatabilities were generally lower than those of given previous studies (Karjalainen et al. 1996, Liinamo et al. 1997, Brenøe et al. 2002, Lindberg et al. 2004, Liinamo 2009, Arvelius & Klemetsdal 2013, Wetten & Aasmundstad 2014). The low heritabilities in this study are mainly due to relatively large residual variances that can be reduced by standardizing the test environment or collecting more precise information about the terrain and conditions and including that in the statistical model used in variance component estimation. In addition, there may be differences in genetic variation between the breeds that also affect the heritability estimates.

The heritability estimate of search was close to what Wetten and Aasmundstad (2014) estimated for Norwegian Elkhounds and Liinamo et al. (1997) for Finnish Hounds. The heritability estimate for search in Finnish Spitz (Karjalainen et al. (1996) was significantly higher than in the studies mentioned earlier, and this may due to the difference of the game, and so, due to the difference of the evaluation itself. Repeatability estimate for search was higher than that in Liinamo et al. (1997), but half of what Karjalainen et al. (1996) estimated. The estimate of the heritability for efficiency was lower compared to Wetten and Aasmundstad (2014) and by Liinamo et al. (1997), but the repeatability estimate was the same as in Liinamo et al. (1997). The model used in the study by Wetten and Aasmundstad (2014) was a single-trait animal model. The estimates of heritability and repeatability of following were also lower than those presented in previous studies (Karjalainen et al. 1996, Liinamo et al. 1997, Liinamo 2009, Wetten & Aasmundstad 2014). These low repeatabilities suggest that the dog does not perform consistent in search and is not constantly as efficient in finding elk in trials. The dog is also incapable of following the elk as good in different trials. Reasons for this behavior may be invisible for the eye, such as ghost trails, the elk being close of the place the dog was released to search, physical condition of the dog, and the behavior of the elk.

The heritability estimates of bark traits were much lower than the estimates in the studies mentioned earlier (Karjalainen et al. 1996, Liinamo et al. 1997, Liinamo 2009, Wetten & Aasmundstad 2014). Also, the heritability of the frequency was lower in this study compared to other studies (Karjalainen et al. 1996, Liinamo et al. 1997, Liinamo 2009) but still among the highest heritabilities analyzed. In a study by Liinamo (2009) the frequency was analyzed both as an auxiliary trait and as a merit score. Both heritability and repeatability of the frequency was higher for the auxiliary trait than for the subjectively evaluated merit score (Liinamo 2009). The merit score is evaluated in the same manner as the frequency in this study, and heritabilities and repeatabilities were similar and low.

The heritability estimate of obedience and cooperation have been among most the variable hunting traits ranging from 0.02 to 0.04 for obedience alone, and from 0.02 to 0.21 for cooperation (Liinamo et al. 1997, Wetten & Aasmundstad 2014). In this study, obedience and cooperation were analyzed together as a single trait. Since obedience traits had the narrowest scoring of the traits considered, the idea of narrow scoring leading to higher estimates of heritability appears to be in contradiction with the results. Adding an effect of owner may increase the heritability especially in obedience traits. Repeatabilities of obedience traits were low compared to previous studies (Liinamo et al. 1997, Brenøe et al. 2002, Arvelius and Klemetsdal 2013).

The heritability estimate of the circle of blank ranging round was about half of that of the study reported by Liinamo et al. (1997) and by Liinamo (2009), but the heritability estimate of time of a ranging round in this study was twice compared to Liinamo et al. (1997). The heritability estimate of the circle of full ranging round was in this study near zero, while in previous studies heritabilities as high as 0.21 (no separation between full and blank) have been reported (Brenøe et al. 2002).

As a conclusion, the elk hunting trial events have multiple varying elements, so the trial data, as it is now, may not offer sufficient information on environmental variables to increase the heritability.

6.5 Genetic and phenotypic correlations

The moderate and strong genetic correlations between search, efficiency, and circles of ranging rounds indicate that the traits have a similar genetic background. The genetic background of search is presumably similar to efficiency, since the genetic correlation of these traits is 0.91. Genetic correlations were high also between the bark traits, the highest genetic correlation being 1.00 between bark time and quality of the bark. The standard errors of genetic correlations were high on traits related to search, following, frequency, and obedience.

Search and following were moderately genetically correlated, and efficiency and following likewise. In search and following the dog uses its' senses to find the elk but following the elk calls more for courage. On the other hand, the genetic correlation between search and following was much higher in the previous studies (Karjalainen et al. 1996, Liinamo et al. 1997). The high standard error may explain this difference. The genetic correlation between search and quality bark was moderate and of the same level compared to that in the previous studies (Karjalainen et al. 1996, Liinamo et al. 1997) indicating that the traits are have rather different genetic background. The genetic correlations between quality of bark and following were much higher than in the previous study by Liinamo et al. (1997).

The lower genetic correlation between the frequency and all other bark related traits could be due to more objective measurement of the frequency. The genetic correlation between the following and the frequency was of the same level as in the previous study by Karjalainen et al. (1996), but the standard error was high in the current study and the results cannot be considered reliable. The genetic correlation between the quality of bark and the frequency was somewhat lower in this study. The genetic correlation between search and frequency was extremely low compared to that in the previous study by Karjalainen et al. (1996).The reason for this may be different way of measurement– auxiliary trait and merit score.

The genetic correlations between the obedience traits were rather strong, except that the genetic correlation between obedience during search and obedience after trial was surprisingly low. The dog may be in higher drive after trial and so harder to be called back. This may cause low genetic correlation. Circles of ranging rounds were negatively correlated with the obedience in genetic sense. However, the estimate is not reliable due to high standard error. Furthermore, the genetic correlation between circle and obedience was of an opposite sign and of different strength than in the study by Brenøe et al. (2002).

The phenotypic correlations were lower than those of previous studies except for the phenotypic correlations between the frequency and both the quality of bark and the following, and between the quality of bark and the following that were of the same level as in previous studies (Karjalainen et al. 1996, Liinamo et al. 1997, Brenøe et al. 2002). Phenotypic correlations were moderate to strong between all bark traits, between search and efficiency, and between the obedience traits, with obedience during search excluded. These correlating traits are similar to each other.

6.5 Genetic trends

The genetic trend of the breeding values has been generally positive except for traits related to obedience. Even though selection indices have been available for hunting traits in the past, the most likely selection criteria of the breeding dogs have been dog's success in in hunting trials and the results of the relatives, mainly parents, offspring, and siblings (Jukka Immonen personal communication). These information sources are also the most important in breeding value estimation. However, in BLUP-evaluation these information sources get correct weight depending on heritability and repeatability of the trait and the number of observations of the dog itself and its relatives. As an example, the youngest sire born in 2014 with the most progeny (15 puppies) had an estimated breeding value of 123.8 in search. Parents of the litter should be selected after maturation if selection is based solely on phenotypic selection. Optimally selection based on estimated breeding values of hunting traits together with phenotypic information of the other traits (such as health, conformation, temperament etc.) is recommended. In population level also proper management of the coefficient of inbreeding is advised.

6.6 Improving estimation of breeding values

There was plenty of residual variation in the estimates of the heritabilities. This unexplained variation should be reduced in order to improve the estimation of the breeding values. Regarding the systematic effects on trial; weather, terrain, physical condition of the dog, and kind of the elk, should be recorded to decrease residual and environmental variation. Judges should be guided to use the whole scale of points and breed-specific scaling could be utilized to keep the trial results comparable between the breeds.

In genetic analyses data limitation should be revised and objective measurements instead of merit scores used. Genetic correlations between merit scores and objective measurements should be estimated to reduce the number of traits in estimation of the breeding values. The information on genetic correlations between similar traits can be utilized in selection. To improve heritability estimates of circle and time more stringent selection of data should be applied. The length of the ranging round does not reflect features of the dog but rather of the group – the handler and the judges and is irrelevant in selection. Breeder effect and owner effect should be estimated to reduce residual variation.

A dog should have multiple trial records before and after maturation because of the effect of the age on performance. In this study the phenotypic data included trial results from a period of five years. Dogs entering the trials are young and potential time to attend trials is between the age of nine months and six years. The data in this study included trial observations from years 2012 to 2016. To improve estimation of the breeding values observations from recent years should be included in the analyses and more observations per a dog would be gained.

7 CONCLUSIONS

The aim of this study was to estimate heritabilities for elk hunting traits in Jämthunds. Based on this study the heritabilities of elk hunting traits in Jämthunds are generally low. The highest heritability was obtained for the search (0.047) and for the frequency (0.033), and the lowest for the obedience during work (close to 0.00). Age, experience, sex, area and time of the trial, snow conditions, and elk find had an effect on dog’s performance in a trial. The effects of judge and litter were marginal. More environmental factors should be included in the data, objectivity of the evaluation of the traits increased, and stricter limitation of the data should be applied to increase the heritabilities.

The genetic and phenotypic correlations between the traits varied from weak negative to strong positive correlations. Based on this study, bark traits have similar genetic background. In addition, search, efficiency, and circle of blank ranging rounds share similar genetic background. At least for the bark traits a sum of the points of the separate bark traits could be used in the genetic evaluation instead of three separate bark traits.

The genetic trends have been positive except in obedience traits. The performance of the dog in elk hunting trials gets better with age, and dogs should be given time to mature before making final breeding selections. Breeding decisions should be based on breeding values due to low heritabilities of the traits.

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Appendix 1: Trial record sheet

SUOMEN KENNELLIITTO
FINSKA KENNELKLUBBEN RY.

Hirvenhaukkukokeen koirakohtainen pöytäkirja

Kokeen järjestäjä			Kennelpiirin numero
Koepaikka	Koemaaston paikkakunta	Aika	☐ Koko kauden koe

Koira

Nimi		Rekisterinumero	
Synt.aika	Rotukoodi	☐ Rokotukset	☐ Tunnistusmerkintä
Koiran emä		Rekisterinumero	
Omistajan nimi		Kotipaikka	
Lähiosoite		Postinumero ja -toimipaikka	

Koetapahtumat

A Hakemaan klo	B Hirvi löytyi klo	C Hakuaika min	D Haun aikana kuljettu matka km	E Löytömatka km / Etäisyys ryhmästä
F Haukkua löytöpaikalla min	G Siirtyi 60 min aikana löydöstä km	H Haukkuaika min	I Kiinteää haukkua min	J Siirtyvää haukkua min
K Ensimmäisen uusintahaukun pituus min	L Työskentely-aika min	M Työskentely-matka km	N Karkotuksia kpl	O Karkotukset yhteensä km
P Pisin haukkuun päättynyt seuraaminen km	Q Uusintahaukut 30 | 10 | < 10	R Ampuma-tilaisuuksia kpl	S Haukkutiheys (hauk./min)	T Koira palaa pakenevan hirven seur. kpl
U Yhteyden-otot kpl	V Koe lopetettiin klo	W Lumipeite cm	X Koira kytkettiin klo	Y Hirvitiheys 1...3 (1 = heikko, 3 = hyvä)
Z Hirvien määrä ja laatu	Å Hirvien määrä alueella (kpl/1000 ha)	L1 Haukkuun päättyneet karkot yht. km	L2 Testattu haukun kuuluvuus km	

Kytkeminen

- ☐ Haun aikana
- ☐ Koira kutsutaan työskentelystä (0–150 min)
- ☐ Koira kutsutaan työskentelystä (150–300 min)
- ☐ Koira kutsutaan työskentelystä erän jälkeen
- ☐ Koira ei ole kytkettävissä

Koe-erän päättyessä

- ☐ Koiralla kiinteä haukku
- ☐ Koira kiinteään haukkuun päättyvässä seuraamisessa
- ☐ Koira kytketään seuraamisesta
- ☐ Koira palaa pakenevan hirven seuraamisesta
- ☐ Jokin muu tilanne

Haku

- ☐ Ryhmä jalkautuu, koira tekee hakulenkkejä
- ☐ Koira tekee hakulenkkejä irtilaskupaikalta
- ☐ Ryhmä etsii koiran hakulenkiltä

Vajaan erän syy

- ☐ Pimeys
- ☐ Ryhmän päätös
- ☐ Muu syy

Ensimmäiset hakulenkit

km	min	ulottuvuus

Löytölenkit

km	min	ulottuvuus	LEK	LEL

Löytöä ei kuultu (toteamaton): LEK = X
Löytö ensimmäiseltä lenkiltä: LEL = X

Vesi ☐ Veteenmenohalu todettu ☐ Työskent.seuraaminen päättyy vesiesteeseen

Vainu ☐ Ilmavainu ☐ Jälkivainu

Virheet ☐ Metsästysinnon ja kestävyyden puute ☐ Koti- tai sorkkaeläimen ajaminen ☐ Hirven ajaminen ☐ Muun riistan haukku tai ajo

Pisteet	tuomari	kerr.	tulos
1. Haku		1,5	
2. Löytötehokkuus		1,0	
3. Löytöhaukku		1,5	
4. Haukkutyöskentelyn laatu		1,5	
5. Pakenevan hirven seuraaminen		1,0	
6. Pakenevan hirven pysäyttäminen		1,0	
7. Haukkuaika		0,5	
8. Haukun kuuluvuus		0,5	
9. Haukun tiheys ja peittävyys		0,5	
10. Yhteistyö ja tottelevaisuus		1,0	
a)	Yhteensä		
b)			
c)			

KOKEEN TULOS	
Loppu-pisteet	
Sijoitus	________ / ________
Palkintosija	

Huomautukset

....

....

....

K	Ryhmätuomarin allekirjoitus	K	Palkintotuomarin allekirjoitus
J	Nimenselvennys	J	Nimenselvennys
Ylituomarin allekirjoitus		Ylituomarin nimenselvennys	

Jakelu: 1.> Kennelliitto 2.> rotujärjestö, 3.> kennelpiiri, 4.> koiranomistaja

4x10.000 07.2012

Appendix 2: Estimates of the random effects

Litter

In “search and find traits there is apparent skewness in following towards upper quartile. Upper and lower whiskers are equal in size.

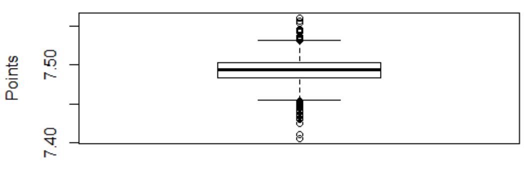

Figure 22 Effect of litter on search

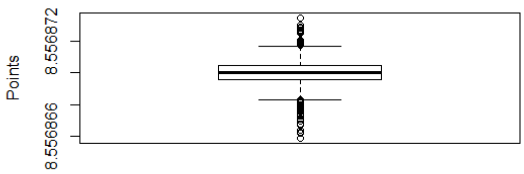

Figure 23 Effect of litter on efficiency

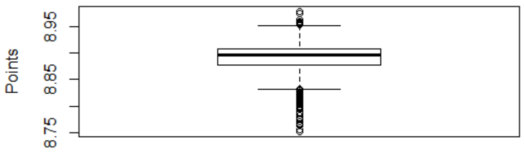

Figure 24 Effect of litter on following

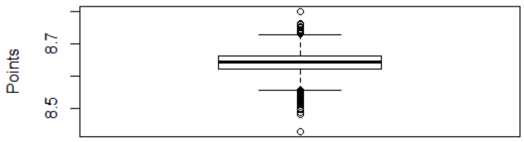

Figure 25 Effect of litter on stopping

In bark traits there is apparent skewness in bark time, audibility, and quality of bark towards upper quartile. Upper and lower whiskers are of equal size.

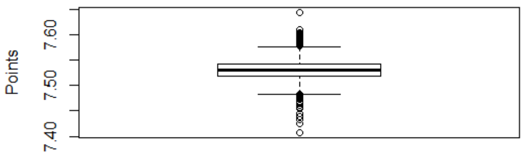

Figure 26 Effect of litter on bark to hold

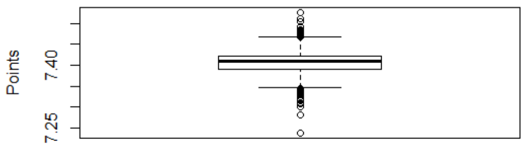

Figure 27 Effect of litter on quality of bark

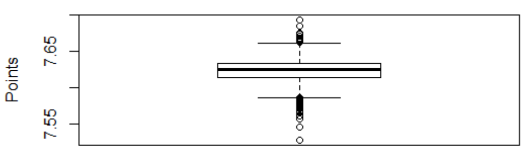

Figure 28 Effect of litter on bark time

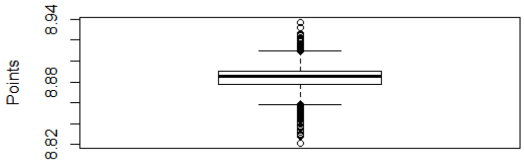

Figure 29 Effect of litter on audibility

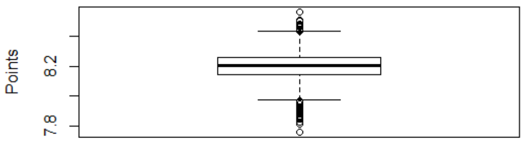

Figure 10 Effect of litter on frequency

In “obedience traits there is apparent skewness in obedience during search towards upper quartile. In “obedience traits there is some skewness in obedience after trial towards lower quartile. Upper and lower whiskers are of equal size.

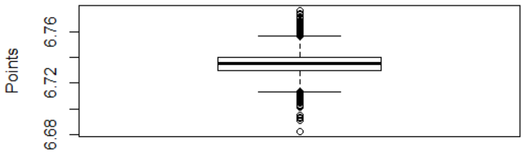

Figure 11 Effect of litter on obedience

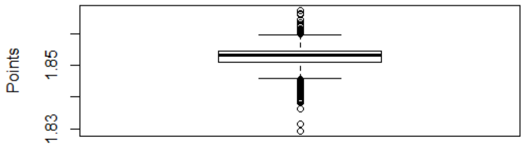

Figure 12 Effect of litter on obedience during search

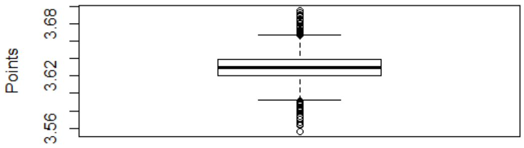

Figure 13 Effect of litter on obedience during work

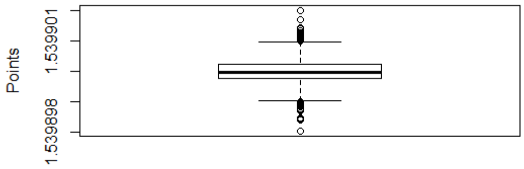

Figure 14 Effect of litter on obedience after trial

In blank ranging rounds there is apparent skewness in circle and length of a ranging round. Upper and lower whisker are of equal size.

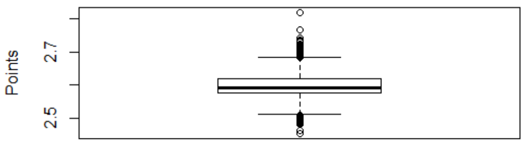

Figure 15 Effect of litter on circle from a ranging round – blank rounds

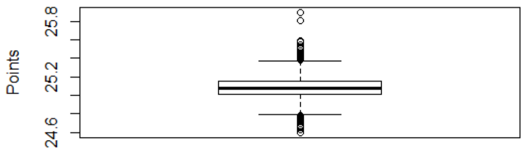

Figure 16 Effect of litter on time from a ranging round – blank rounds

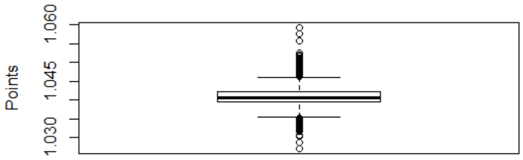

Figure 17 Effect of litter on length from a ranging round – blank rounds

In blank ranging rounds there is apparent skewness in circle and length of a ranging round. Upper and lower whisker are of equal size.

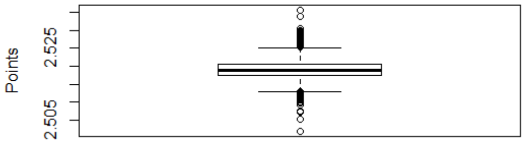

Figure 18 Effect of litter on circle from a ranging round – full rounds

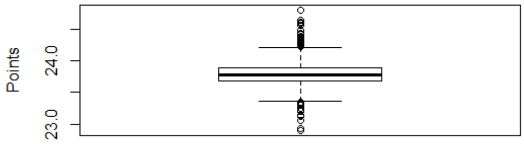

Figure 19 Effect of litter on time from a ranging round – full rounds

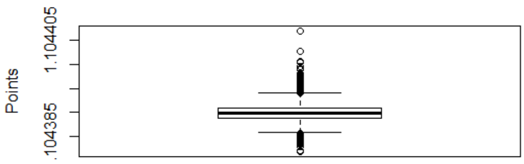

Figure 20 Effect of litter on length from a ranging round – full rounds

Chief judge

In following the effect of judge was skewed towards upper quartile.

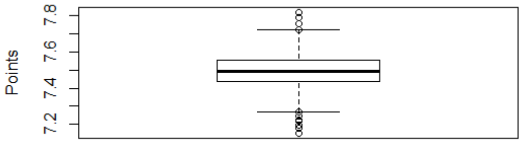

Figure 21 Search

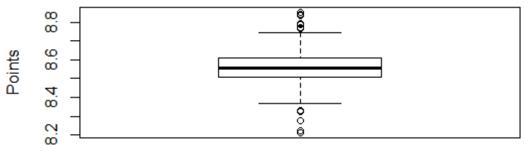

Figure 22 Efficiency

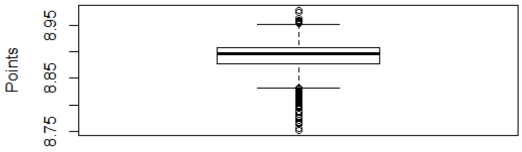

Figure 23 Following

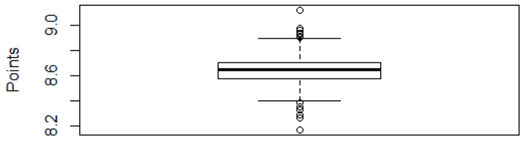

Figure 24 Stopping

In bark to hold, bark time, and frequency the effect of judge was skewed towards the lower quartile.

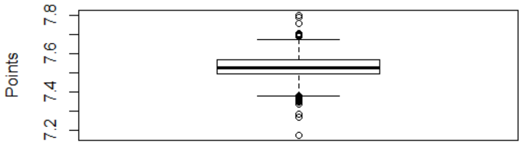

Figure 25 Bark to Hold

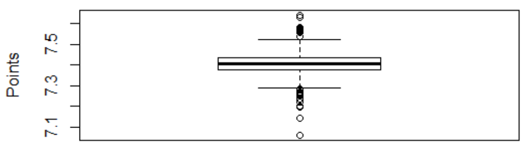

Figure 26 Quality of Bark

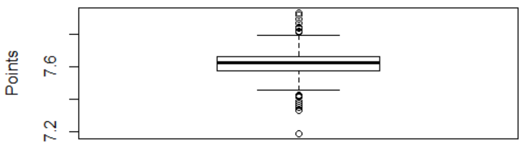

Figure 27 Bark time

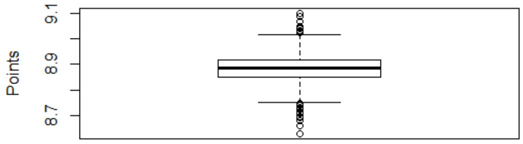

Figure 28 Audibility

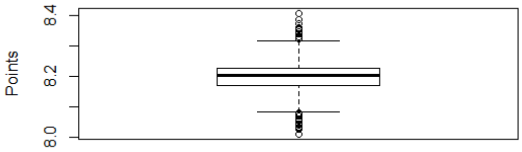

Figure 29 Frequency

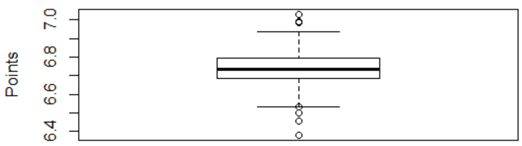

Figure 30 Obedience

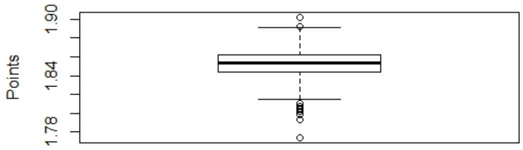

Figure 31 Obedience during search

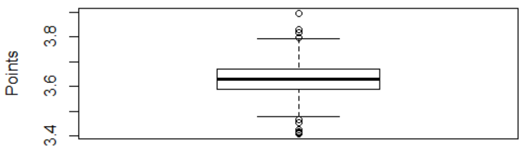

Figure 32 Obedience during work

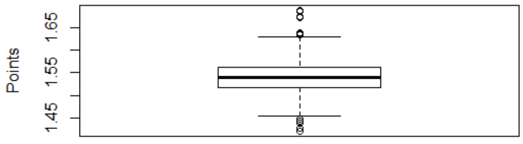

Figure 533 Obedience after trial

In circle of blank rounds the effect of judge was skewed towards lower quartile.

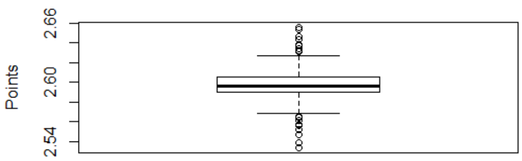

Figure 34 Circle of a ranging round – blank rounds

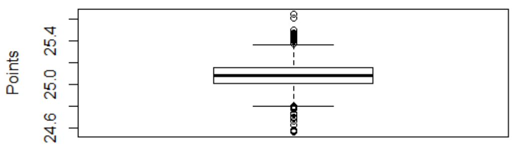

Figure 535 Time of a ranging round – blank rounds

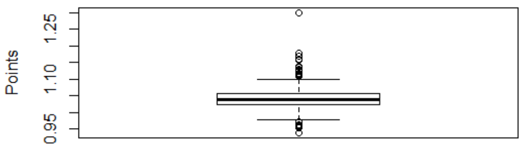

Figure 36 Length of a ranging round – blank rounds

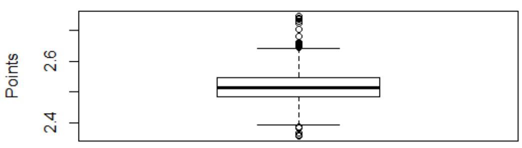

Figure 537 Circle of a ranging round – full rounds

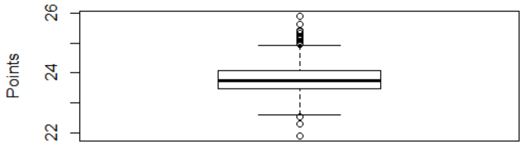

Figure 38 Time of a ranging round – full rounds

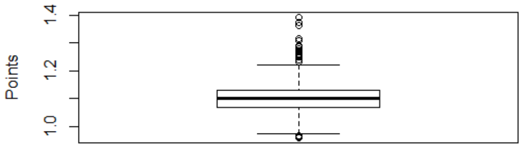

Figure 59 Length of a ranging round – full rounds

Appendix 3: Complete table of genetic and phenotypic correlations between the traits

Audibility	Bark time	Stopping	Following	Quality of bark	Bark to hold	Efficiency	Search	Trait
0.10	0.08	0.08	0.09	0.09	0.09	0.43	1	Search
0.17	0.15	0.13	0.14	0.15	0.14	1	0.91	Efficiency
0.57	0.58	0.42	0.01	0.60	1	0.42-0.43	0.38	Bark to hold
0.83	0.95	0.88	0.20	1	0.83	0.41-0.42	0.41	Quality of bark
0.14	0.17	0.25	1	0.73	0.45	0.25	0.34-0.37	Following
0.74	0.89	1	0.73	0.98	0.75	0.58-0.61	0.47	Stopping
0.84	1	0.96-0.97	0.72	1.00	0.85	0.59	0.29	Bark time
1	0.96	0.94	0.66	0.98	0.78-0.79	0.50	0.50	Audibility
0.51	0.49	0.51	0.28	0.56	0.55	0.17	0.05	Frequency
0.45	0.47	0.62	-0.03	0.49	0.24	0.50	0.14-0.20	Obedience
-0.13—	-0.19	-0.24	-0.56	-0.22	0.04	-0.34	-0.61	Obedience during search
0.39	0.10	0.56-0.58	-0.28—	0.04	-0.02	0.55	-0.53--0.16	Obedience during work
0.71	0.41	0.79	0.50	0.38-0.73	0.49	0.33-0.35	0.30	Obedience after trial
0.36-0.41	0.23	0.36-0.38	0.31	0.23-0.33	0.24	0.70	0.94	Circle blank
0.65	0.44	0.40	0.52	0.45	0.40	0.78	0.77	Circle full

Trait	Circle full	Circle blank	Obedience after trial	Obedience during work	Obedience during search	Obedience	Frequency
Search	0.21	0.41	0.07	0.04	-0.10	0.03	0.10
Efficiency	0.28	0.09	0.10	0.09	-0.10	0.07	0.18
Bark to hold	0.06	0.01	0.23	0.22	-0.05	0.23	0.55
Quality of bark	0.03	-0.01	0.51	0.42	-0.10	0.48	0.77
Following	0.02	0.02	0.20	0.13-0.16	-0.05	0.18	0.12
Stopping	0.02	0.00	0.50	0.41	-0.08	0.47	0.67
Bark time	0.04	-0.01	0.50	0.36	-0.10	0.47	0.77
Audibility	0.05	-0.01	0.41	0.34	-0.08	0.38	0.87
Frequency	0.04	-0.01	0.32	0.31	-0.08	0.34	1
Obedience	0.00	-0.02	0.74	0.77	0.19	1	0.11
Obedience during search	-0.04	-0.10	-0.04	-0.03	1	0.73	-0.15
Obedience during work	0.01	-0.01	0.38	1	0.93	0.88	0.00
Obedience after trial	0.01	0.00	1	0.61-0.65	0.27	0.75	0.36
Circle blank	0.12	1	0.16	-0.96	-.062	-0.27	0.04
Circle full	1	0.82-0.83	-0.07—0.01	-0.22	-0.92—0.94	-0.25	0.20